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Some 13.8 billion years ago, our universe sprang into existence... again. According to some very recent research – and a study that dovetails with Nobel Prize winner Sir Roger Penrose – it's thought that there were multiple Big Bangs, and there could be many more in the very distant future. I'll leave you to read all about it in our cover feature this issue, and as you leaf through the pages to get there, take a moment to absorb the latest news from around the universe this month.

Also this month, we caught up with the author of *Hidden Figures*, Margot Shetterly, about the challenges in uncovering the story behind the women whose work propelled America into space and why human computers are suddenly looming large in the public consciousness. Elsewhere, we reveal the space scandals that changed the face of space exploration – from drunk astronauts and secret marriages and death cover ups, you'll be amazed at what you'll discover. I'll see you next time, where **All About Space** delves into the future of Virgin Orbit and the future of UK space launches. Be sure to pick us up next issue for our special report.

GEMMA LAVENDER
Editor

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"Each represented a certain slice of the narrative in terms of the development of women in the workplace"

Margot Shetterly

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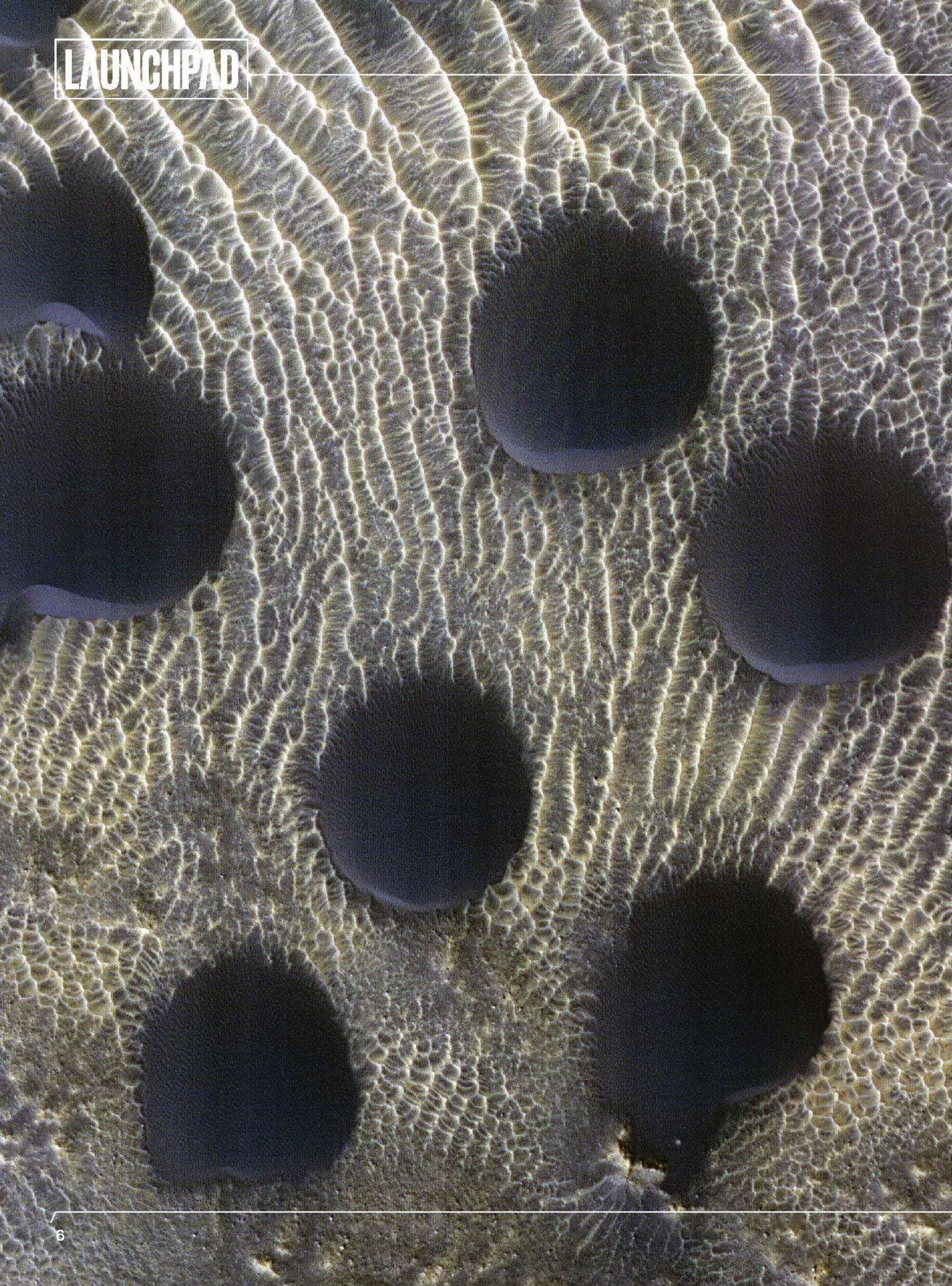
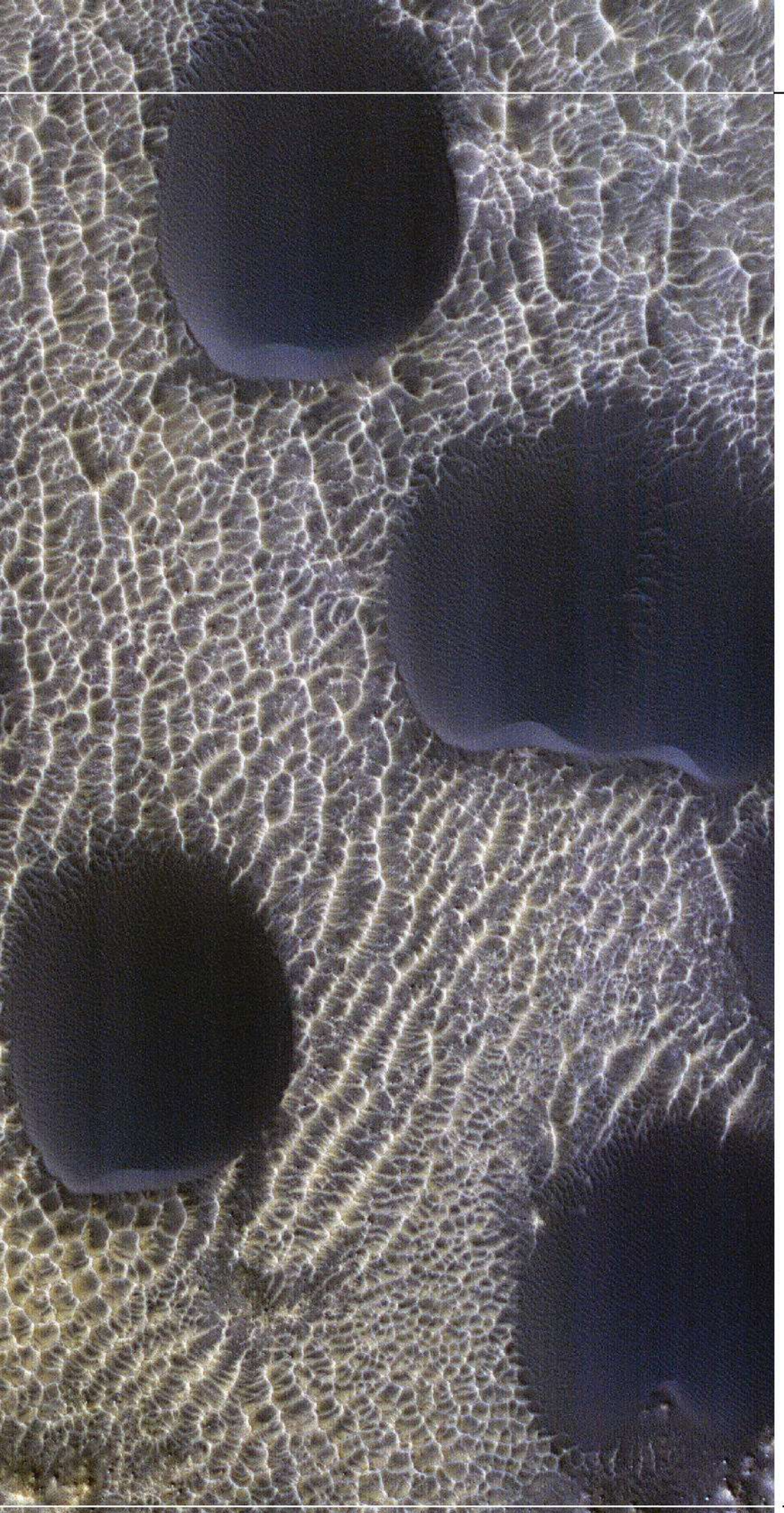




2 March 2023

Strange circular dunes spotted on Mars

Planetary scientists have captured an image of near-perfectly circular sand dunes on the surface of Mars. While sand dunes across the Red Planet come in a wealth of shapes and sizes, such well-defined circles are unusual. The slight asymmetry in the sand dunes shows their steep sides are orientated towards the south. The University of Arizona, which operates the High-Resolution Imaging Experiment (HiRISE) camera used to take the image, pointed out in recent research that this indicates that sands are blown southwards, though the Martian winds may be variable. The image was taken at a latitude of 42.505 degrees and a longitude of 67.076 degrees. It comes as part of a series of pictures taken by the HiRISE camera that orbits Mars on the Mars Reconnaissance Orbiter (MRO) spacecraft.

The sand dune image was taken while the MRO was at an altitude of around 300 kilometres (185 miles) over the Martian surface. Each pixel in the image represents 9.8 inches (25 centimetres). This is just one of 60 sites on Mars being monitored by HiRISE. The high-resolution camera has been orbiting the Red Planet since the MRO reached Mars in 2006, conducting the first dedicated survey of the planet's sand dunes. Collecting repeated observations of sand dunes over the Martian year – lasting 687 Earth days – has allowed planetary scientists to monitor how fast the dunes move. This has revealed that sand dunes from the equator to the poles are advancing at rates of up to one metre (3.3 feet) per Martian year.

© NASA; JPL-Caltech

17 March 2023

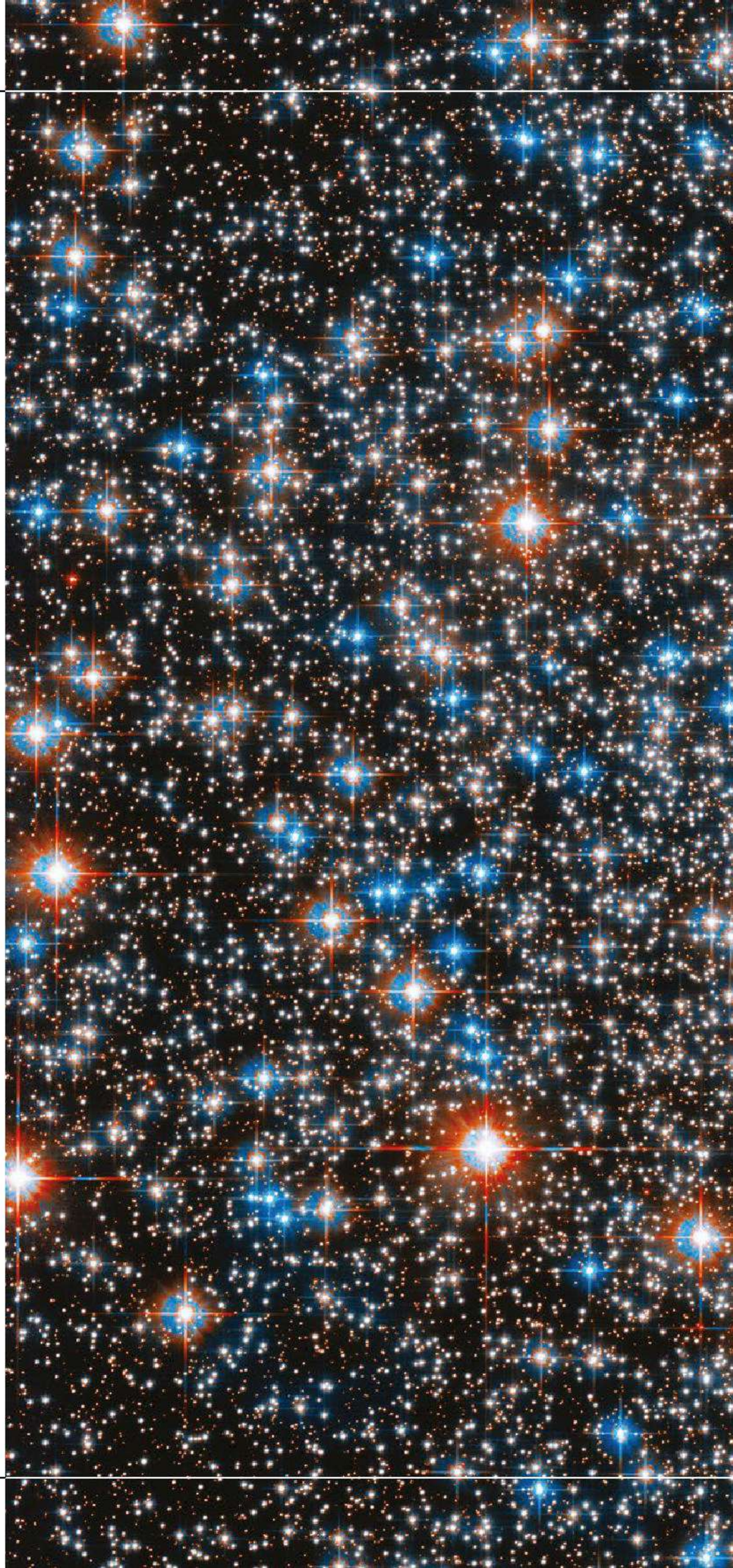
Star-studded cluster

A distant cluster sparkles with ancient stars in a gorgeous new image from the Hubble Space Telescope. The dazzling photo shows just a pocket of Messier 55, a globular cluster in Sagittarius that harbours about 100,000 stars. Astronomers say that some of these stars – especially those in Messier 55's centre – twinkle with changing brightness. The combined gravity of Messier 55's stars pulls the cluster into a spherical shape, a common trait shared by more than 150 such objects that occupy the Milky Way.

Astronomers know little about the elusive Messier 55 itself, which is about 17,000 light years from Earth. The cluster is 100 light years in diameter and spans about two-thirds the width of a full Moon as seen from Earth. Messier 55 is relatively bright, but for observers in the Northern Hemisphere, Earth's atmosphere obscures the cluster, so its stars are tough to spot. "While Messier 55 is large and reasonably bright, it's lacking a dense core and many of its stars are quite faint, making it hard to observe in non-optimal conditions," NASA representatives said.

When the French astronomer Nicolas-Louis de Lacaille discovered Messier 55 in 1752, he noted that the cluster "resembles an obscure nucleus of a big comet". Soon the hunt was taken up by Charles Messier, a French astronomer and the publisher of the famous Messier catalogue of 110 deep-sky objects – one of which is Messier 55. It took Messier 26 years to find the cluster, and when he finally spotted it in 1778 from his observatory in Paris, he described it as "a nebula which is a whitish spot of about six arcminutes extension, its light is even and does not appear to contain any star".

Hubble faces none of the challenges that those Earth-based observers did. The observatory has a splendid seat from its orbit above Earth's atmosphere to snap the clearest views of Messier 55, and can even resolve its individual stars. The telescope, which launched to Earth orbit in 1990 and is still going strong, has snapped sparkling pictures of at least 93 of the 110 Messier objects to date.



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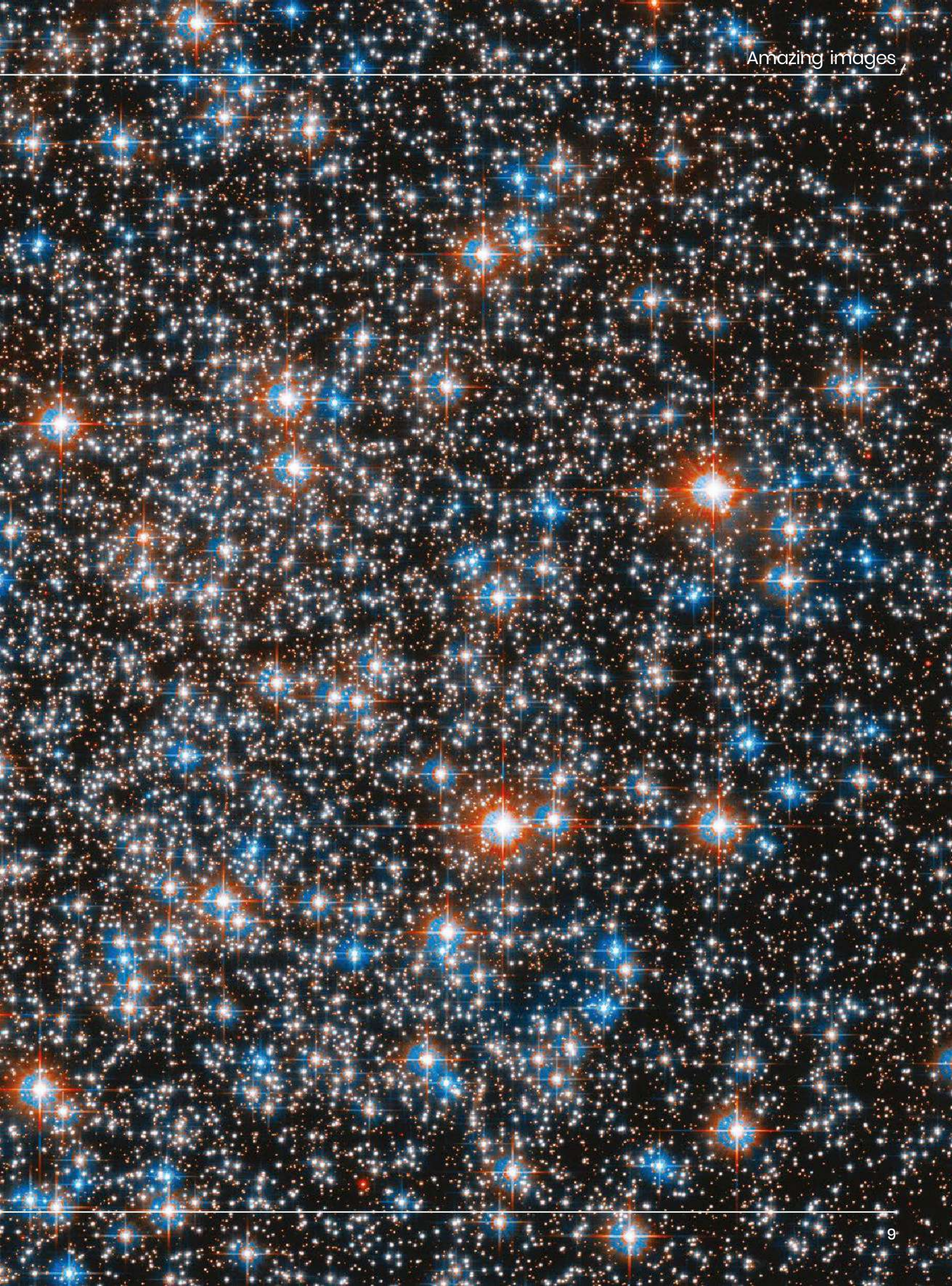


Delays to NASA's VERITAS mission a major blow for Venus exploration

Reported by Sharmila Kuthunur

Delays to the first of three missions making the long awaited return to the scorching planet Venus might affect the two other missions set to explore our planetary neighbour. Late last year, NASA pushed the VERITAS (or Venus Emissivity, Radio Science, InSAR, Topography and Spectroscopy) mission, originally scheduled to fly in 2027 to inaugurate the 'Decade of Venus', to no earlier than 2031. However, the White House's 2024 budget proposal for NASA, announced in March 2023, holds the mission funding for VERITAS at a mere $1.5 million per year for the near future, placing the mission in a 'deep freeze'. Its indefinite delay has disbanded the mission's engineering wing, and scientists are now worrying about its impact on two other related missions to Venus.

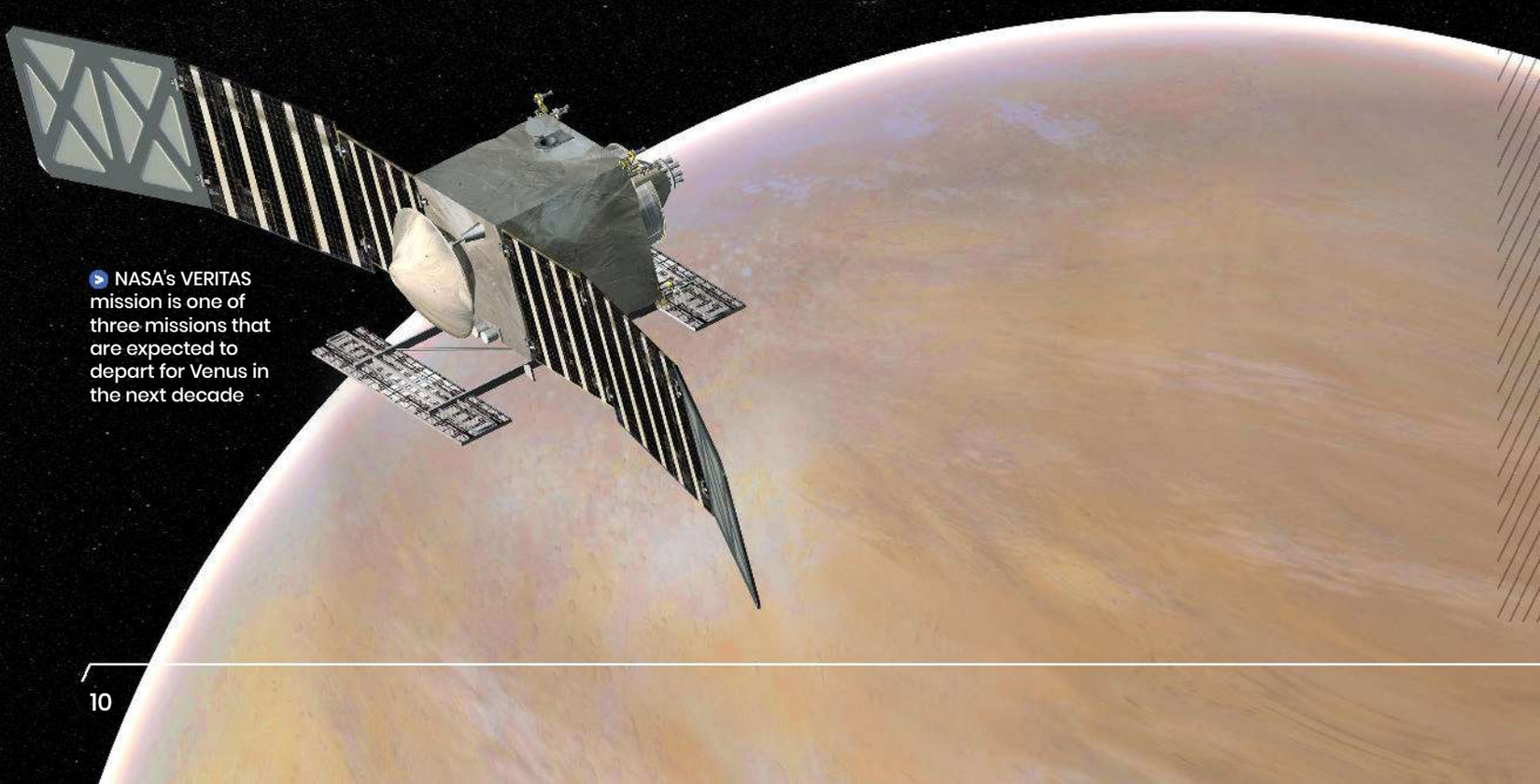
VERITAS was supposed to be the first mission to return to Venus since NASA's Magellan spacecraft orbited it nearly 30 years ago. The spacecraft "will contribute foundational measurements needed for all types of Venus fundamental science," Darby Dyar, VERITAS' deputy principal investigator, said. Some of those measurements were intended to support another NASA Venus mission – DAVINCI (or Deep Atmosphere Venus Investigation of Noble gases, Chemistry, and Imaging). Scheduled to reach Venus in the early 2030s, DAVINCI will drop a probe into the planet's thick clouds that will make its way to the surface. Per the original plan, VERITAS would have already arrived at Venus prior to DAVINCI's launch, so scientists were hoping to use its data to select the best landing site for DAVINCI's probe. "The surface mapping provided by VERITAS would have been incredibly useful for fine-tuning the deployment of DAVINCI," Stephen Kane, an astronomer at the University of California in Riverside, said.

Another mission originally intended to benefit from VERITAS data is EnVision, which is led by the European Space Agency (ESA) and scheduled to launch in the early 2030s to study the climate on Venus. Now, EnVision is scheduled to visit the planet around the same time that delayed VERITAS will arrive – if it survives NASA's budget issues. This outcome is "less than ideal when the EnVision team was hoping to have the VERITAS data already in hand," Paul Byrne, an astronomy professor at Washington University in St. Louis, Missouri, said.

The parallel missions also means identical instruments on both missions would need to be built at the same time. For example, the German Aerospace Center (or DLR) is building the Venus Emissivity Mapper (VEM) for VERITAS and VenSpec-M for EnVision.

Scientists are also worried that having VERITAS and EnVision at Venus concurrently will result in less than ideal output for at least some of the expected science, including now having shorter than preferred timelines for detecting Venusian volcanoes. For example, the VEM and VenSpec-M mapping instruments on both missions will look for active lava flows on the planet's surface, which could provide strong evidence that the planet is still volcanically active. Such findings will add to the recent discovery of an active volcano on Venus.

The discovery was possible because two images clicked eight months apart showed that a volcanic vent had grown noticeably larger and also changed its shape, reflecting recent volcanic activity. Scientists hope to find similar changes with upcoming missions, which is why the arrivals of VERITAS and EnVision were staggered initially. While VERITAS' engineering team is currently standing down as directed by NASA, its science team is supported by limited funding of $1.5 million a year and continues to prepare for the mission while exploring ways to move the launch date to earlier than 2031.



NASA's VERITAS mission is one of three missions that are expected to depart for Venus in the next decade

Scientists may have uncovered the oldest evidence of a meteoroid hitting Earth

Reported by Sascha Pare

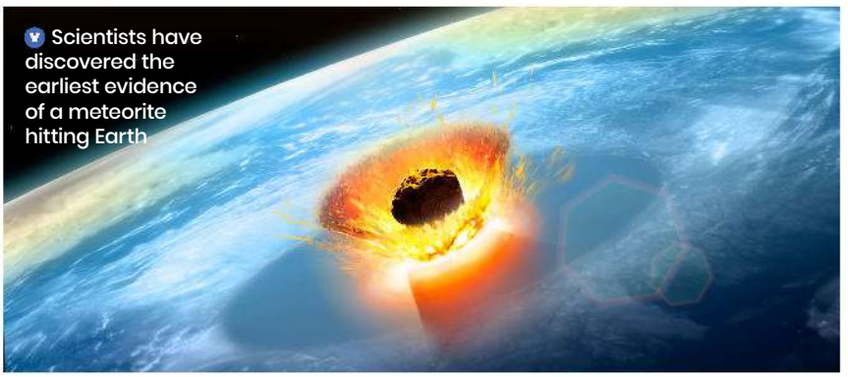
Scientists in Australia have unearthed 3.48 billion-year-old rock fragments that may be the earliest evidence of a meteorite crashing into Earth. The fragments, known as spherules, may have formed when the meteoroid slammed into the ground, spraying melted rock into the air. This melted rock then cooled and hardened into pinhead-size beads that became buried over the aeons. The scientists concluded that the spherules, which they drilled up from a group of volcanic and sedimentary rocks called the Dresser Formation of the Pilbara Craton in Western Australia, are "the oldest evidence of a potential bolide impact in the geologic record of Earth." A bolide is a large meteoroid that explodes in the atmosphere while falling to Earth.

Until now, the oldest evidence of meteoroid impacts were 3.47 billion-year-old spherules, also from Pilbara Craton, and 3.45 billion-year-old fragments found in Kaapvaal Craton, in South Africa. "This new research documents ejecta in slightly older rocks, which have an age of 3.48 billion years old (about 10 million years older than previously found)," Chris Yakymchuk, a geologist at the University of Waterloo in Canada who was not involved in the research, said.

The scientists discovered the spherules in 2019 in cores of sedimentary rock and dated them using isotopes, versions of the same chemical element that have different masses due to the numbers of neutrons in their nuclei. "This is a robust and reliable dating technique," Yakymchuk said. "We have a good idea of their age based on isotope dating of the mineral zircon." The team concluded that the spherules were almost certainly of alien origin due to their chemical composition. They also noted that the fragments had the characteristic dumbbell and teardrop shapes of impact spherules and contained bubbles, which tend to form when splashes of melted rock solidify after a meteoroid strike.

A 2012 study claiming to have uncovered the world's oldest meteor crater triggered a heated debate among scientists. But when geological forces wipe out a crater, spherules are sometimes all that's left of the event. "There are two groups of impact-related rocks," Yakymchuk said. "The first group is where there is still an impact crater preserved – the oldest known one is the 2.23 billion-year-old Yarrabubba structure in Western Australia. The second group is where we have fragments of rock and minerals that were created through an impact, but they have been ejected from the impact crater and are now found in rocks."

The team is now studying the rocks which encased the spherules and analysing the different layers of sediment they drilled up to refine their understanding of the strike. Ancient bombardments like this one shaped the conditions on early Earth and hold rare clues about the history of our planet.



Scientists have discovered the earliest evidence of a meteorite hitting Earth

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Aliens could be hiding in the 'terminator zones' on planets with eternal night

Reported by Robert Lea

Two of Uranus' moons may have active oceans that are pumping material into space, a new study finds. The realisation came via the discovery of strange features in radiation data collected by NASA's Voyager 2 spacecraft as it passed the planet almost four decades ago. The new findings, concerning the moons Ariel and Miranda, also support the idea that Uranus' five largest satellites could have subsurface oceans, a notion suggested by Voyager 2 flyby observations.

The observations of Voyager 2 showed that one or two of the ice giant's 27 known moons are adding plasma particles into the Uranus system. This detection came in the form of 'trapped' energetic particles the spacecraft spotted as it departed the ice giant. The mechanism by which Miranda and/or Ariel may be doing this is currently unknown, but there is one very tantalising possible cause: one or both of the icy moons may possess a liquid ocean beneath their frozen surface that's actively blasting plumes of material into space.

Similar particle-releasing moons exist around Uranus' fellow Solar System ice giant Neptune and the gas giants Jupiter and Saturn. In the case of the Jupiter moon Europa and Saturn's Enceladus, it was the examination of particle and magnetic field data that provided the first hints that these are ocean moons. "It isn't uncommon that energetic particle measurements are a forerunner to discovering an ocean world," Ian Cohen, of the Johns Hopkins Applied Physics Laboratory (APL) said. "We've been making this case for a few years now, that energetic particle and electromagnetic field measurements are important not just for understanding the space environment but also for contributing to the grander planetary science investigation. It just goes to show how valuable it can be to go to a system and explore it first-hand."

Virgin Orbit files for bankruptcy after funding efforts fail

Reported by Sharmila Kuthunur

Virgin Orbit filed for bankruptcy on 3 April, a move that comes shortly after the satellite launch company failed to secure two financing deals and furloughed most of its staff. The California-based company has started the process for a Chapter 11 bankruptcy, which is commonly known as 'reorganisation bankruptcy' and allows the company to continue basic operations while it looks for a buyer. Virgin Investments Limited, which is also part of billionaire Richard Branson's Virgin Group and owns 75 per cent of Virgin Orbit, will provide $31.6 million in support to keep the company afloat until its sale.

Virgin Orbit's 'Start Me Up' mission suffered a rocket launch failure in January 2023 due to a technical error, resulting in the loss of nine customer satellites. By mid-March, the company had paused operations and announced layoffs for about 90 per cent of its workforce. The company was in conversation with two financers but failed to secure a deal, which seemed to be the last straw and the determining factor behind the company's decision to file for bankruptcy. CEO Dan Hart credited the company for developing a "new and innovative method" to launch satellites into orbit and expressed confidence that the company would get a buyer interested in using the tech to loft satellites in the future. Virgin Orbit employed an air-launch system, in which a carrier plane hauled a rocket high into the sky and dropped it at altitude. "While we have taken great efforts to address our financial position and secure additional financing, we ultimately must do what is best for the business," Hart said. "We believe that the cutting-edge launch technology that this team has created will have wide appeal to buyers as we continue in the process to sell the company."

An illustration of an Earth-like planet that is locked with one side always facing its sun, and one side in eternal darkness

Virgin Orbit's Boeing 747 carrier plane Cosmic Girl photographed releasing the company's LauncherOne rocket during a July 2019 drop test

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IS THE UNIVERSE DUE ANOTHER BIG BANG?

New theories and observations are shedding fresh light on the very beginnings of the cosmos, and the formation of the first stars and galaxies. But they're also revealing new and unexpected mysteries

Reported by Giles Sparrow

Ask any astronomer about the very beginnings of the universe, and they're likely to describe the Big Bang theory. Some 13.8 billion years ago, they'll say, the universe was born out of nothing, in an explosion that unleashed the expanding dimensions of space and time, alongside vast amounts of energy. In the moments that followed, most of this energy transformed into the building blocks of matter – subatomic particles of varying mass and complexity, which eventually came together to form simple atoms, and then coalesced to create giant, short-lived stars and the nuclei of the first galaxies.

There's a wealth of evidence to show that the Big Bang theory is broadly correct. For instance, even today the universe is still growing at tremendous speed, with widely separated galaxies and galaxy clusters being pulled apart as the space between them expands. What's more, when powerful telescopes focus on the galaxies farthest from Earth (whose light set out on its journey towards us many billions of years ago), they see violent star systems still in the process of formation. Most tellingly of all, the entire universe is filled with the weak 'afterglow' of the Big Bang itself – the Cosmic Microwave Background Radiation (CMBR) that comes from all over the sky and is otherwise inexplicable.

But even if the basics of the Big Bang are well established, that doesn't mean there aren't still questions to answer. The biggest mysteries of all lie at either end of the process – at the moment when space and time were supposedly 'created', and a few hundred million years later, in the period when the first stars and galaxies began to form. On Christmas Day 2021, NASA's enormous James Webb Space Telescope blasted off on a European Space Agency Ariane V rocket, with a mission to answer at least some of these big questions. The Webb's vast mirror is designed to capture infrared radiation with longer wavelengths (and less energy) than visible light. This includes radiation from the most distant (and therefore earliest) stars and galaxies, emitted as visible light but stretched into the infrared during its long journey across ever-expanding space. This shifting of light into the infrared means the earliest period of cosmic evolution is beyond the limits of instruments such as the Hubble Space Telescope, which work mostly in visible light, so Webb is bringing a whole generation of early galaxies into view – with surprising results.

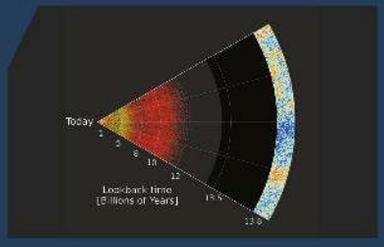
Astronomers have long assumed that galaxies develop in size and shape over time. Large spiral galaxies like our Milky Way are thought to have developed their structure after countless mergers between smaller irregular galaxies, while huge balls of stars known as elliptical galaxies appear to be the result of mergers and collisions between spirals. For this reason and others, the first galaxies that formed are assumed to have been very small, lightweight and faint.

Yet when Webb trained its arsenal of instruments on a small patch of sky close to the famous Big Dipper star pattern for many hours, it revealed something surprising. Hidden within the 'deep field' image, Dr Erica Nelson of the University of Colorado Boulder found half a dozen galaxies that were both extremely red – and therefore distant and very early in cosmic history – and unusually bright. If the brightness of the galaxies is a good indication of their mass (as it usually is) then it seems that some of these bright early galaxies could be as heavy as our own Milky Way. "It's bananas," says Nelson. "You just don't expect the early universe to be able to organise itself that quickly. These galaxies should not have had time to form."

The discovery is so surprising, in fact, that some astronomers have nicknamed the new discoveries "universe breaker" galaxies. That's because they threaten to undermine a highly successful standard model used for understanding large-scale cosmic evolution. Known as Lambda-CDM, this model balances the strength of dark energy – a mysterious force that accelerates the rate of expansion of space, represented by the Greek letter Lambda – against the gravitational attraction of cold dark matter, the invisible and transparent material that vastly outweighs normal matter in the universe, and can only be detected through its gravitational influence. Dark matter's

COSMIC TIME MACHINE

Because even light has a speed limit, powerful telescopes can act as cosmic time machines, allowing astronomers to look back across the history of the Universe. This map from the Sloan Digital Sky Survey charts relatively nearby galaxies and galaxy clusters (yellow) and more distant but bright quasars (red) in terms of their 'lookback time' – the amount of time their light has travelled to reach us. Between the most distant quasars and the 'cosmic dark age' before galaxies began to form lies the mysterious zone of galaxies whose light has been stretched beyond the visible range – the region now being probed by the Webb.



© Getty; Anand Raichoor and the SDSS collaboration

unusual properties allowed it to begin coalescing and forming structures within the expanding incandescent fireball of the early universe, at a time when normal matter was still unable to clump together. The result was a pattern of 'ripples', tiny variations in the density of the universe, imprinted on the CMB that escaped across space as the fireball cleared about 380,000 years after the Big Bang. In the long 'cosmic dark age' that followed, gravity from the ripples attracted the normal matter that eventually formed the first stars and galaxies.

Computer simulations have demonstrated that, with certain parameters for the behaviour of both dark energy and dark matter, Lambda-CDM results in a Universe very like the one we see today, However the model also predicts that an early generation of small galaxies that took a billion years or more to merge and form more substantial systems. A recent study by Dr Mike Boylan-Kolchin, an associate professor at the University of Texas at Austin showed that the massive galaxies seen in the Webb push at the uppermost limits of what's permitted by Lambda-CDM, and predicted that many more 'universe breakers' are likely to be discovered elsewhere in the sky. "If the masses are right, then we are in uncharted territory," Boylan-Kolchin says. "We'll require something very new about galaxy formation or a modification to cosmology."

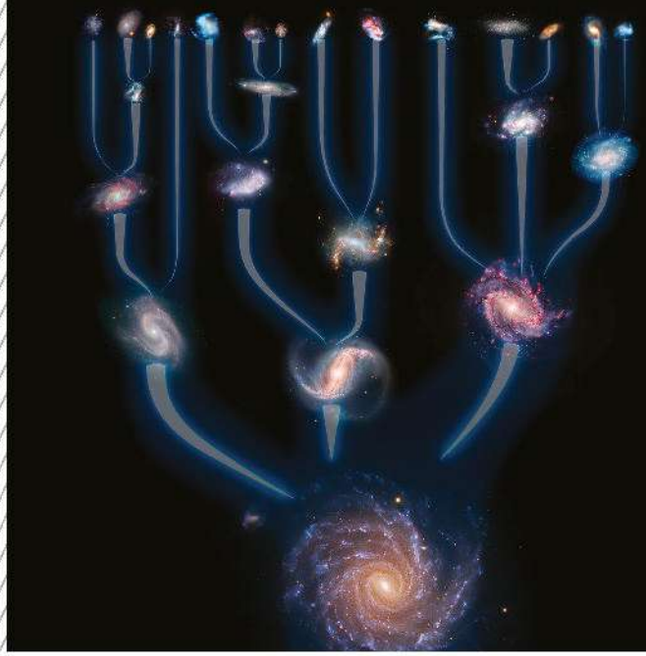
One way to resolve the puzzle would be if the rules of galaxy formation were somehow different in these ancient times; if early galaxies incorporated much more of their available matter into stars, this would allow them to appear brighter even if they were relatively small and lightweight by today's cosmic standards. "Another possibility is that these things are a different kind of weird object, such as faint quasars," suggests Nelson. In this scenario, the galaxies' excess brightness would be due not to their stars, but to the activity of supermassive black holes within them, feeding on gas and dust from their immediate surroundings and emitting radiation in a similar but much more restrained way to the violent active galaxies known as quasars.

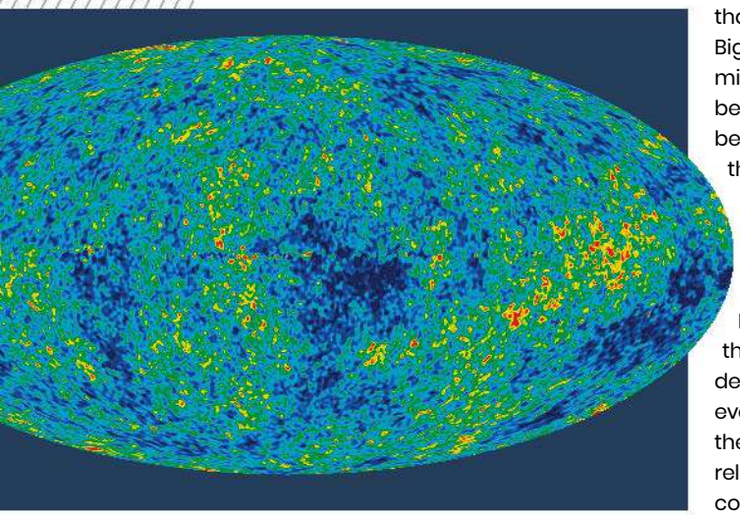
One other alternative explanation for the galaxies is even more intriguing: what if it's not the brightness of the galaxies that's wrong, but our estimate of their distance, based on their redness and our current model of cosmic expansion? "One of the most extreme possibilities is that the universe was expanding faster shortly after the Big Bang than we predict," says Boylan-Kolchin, "which might require new forces and particles." So could there be something wrong with our understanding of the behaviour of space itself in the early universe? While this is only one possible solution to the curious Webb observations, some theoretical cosmologists working at the other end of the Big Bang story have recently been wondering the same thing.

A longstanding problem with the traditional Big Bang theory is the idea that in its first moment, the universe was a singularity – a single, infinitely dense point instant in space and time, out of which everything emerged. Singularities are points at which the mathematics of general relativity, which describe the relations between space, time and matter, break down completely. "The modern interpretation of singularities in

GROWING GALAXIES

Studies of individual galaxy collisions and computer simulations based on the Lambda-CDM model both suggest that galaxies grow in size and complexity through repeated collisions and mergers. As a result, astronomers expect to only find small, faint galaxies in the early universe.



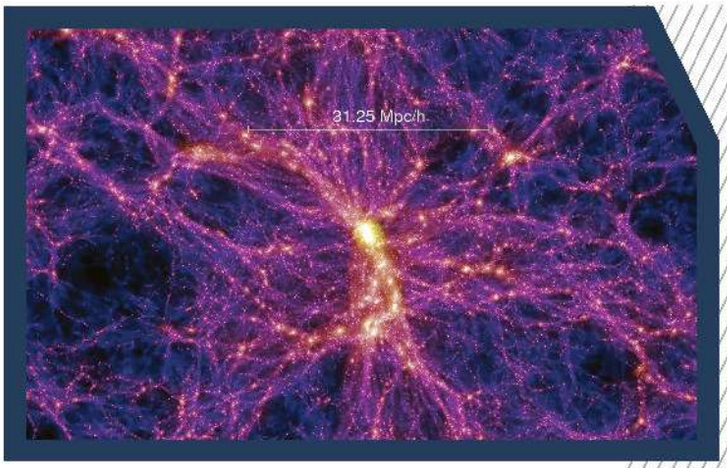


general relativity is that they represent a break-down of the theory, and therefore they need to be avoided," says Dr Marco Bruni of the University of Portsmouth's Institute of Cosmology and Gravitation.

One possible way around this problem preoccupied Stephen Hawking in the later decades of his career, and is the subject of a new book, *On the Origin of Time*, by his long-time collaborator Professor Thomas Hertog. Hawking and Hertog concluded that, due to its tiny scale, the early universe can only be understood through the equations of quantum physics. This would make the first moments of the universe inherently unpredictable, but might also cause space and time to 'blend together' – if you could wind the clock back, you would find time itself becoming increasingly spacelike and running ever more slowly, until the universe became static and timeless without ever quite reaching the point of singularity.

Along with graduate student Molly Burkmar, however, Bruni has been investigating another intriguing possibility. "We instead replace the singularity with a bounce within general relativity, using the negative pressure of dark energy and the positive curvature of space," they explain. Bruni and Burkmar's study was inspired in part by the similarities between inflation – a phenomenon that drove violent expansion very shortly after the Big Bang – and the dark energy that, after apparently remaining dormant, has caused the expansion of the universe to speed up once again in the past 5 billion years. Inflation is a core element of the modern Big Bang theory – an event in which one small fragment of the infant universe blew up to enormous size, magnifying tiny quantum fluctuations within it until they were large enough to become the seeds of large-scale structure in the later universe, before coming to an end just as suddenly as it began.

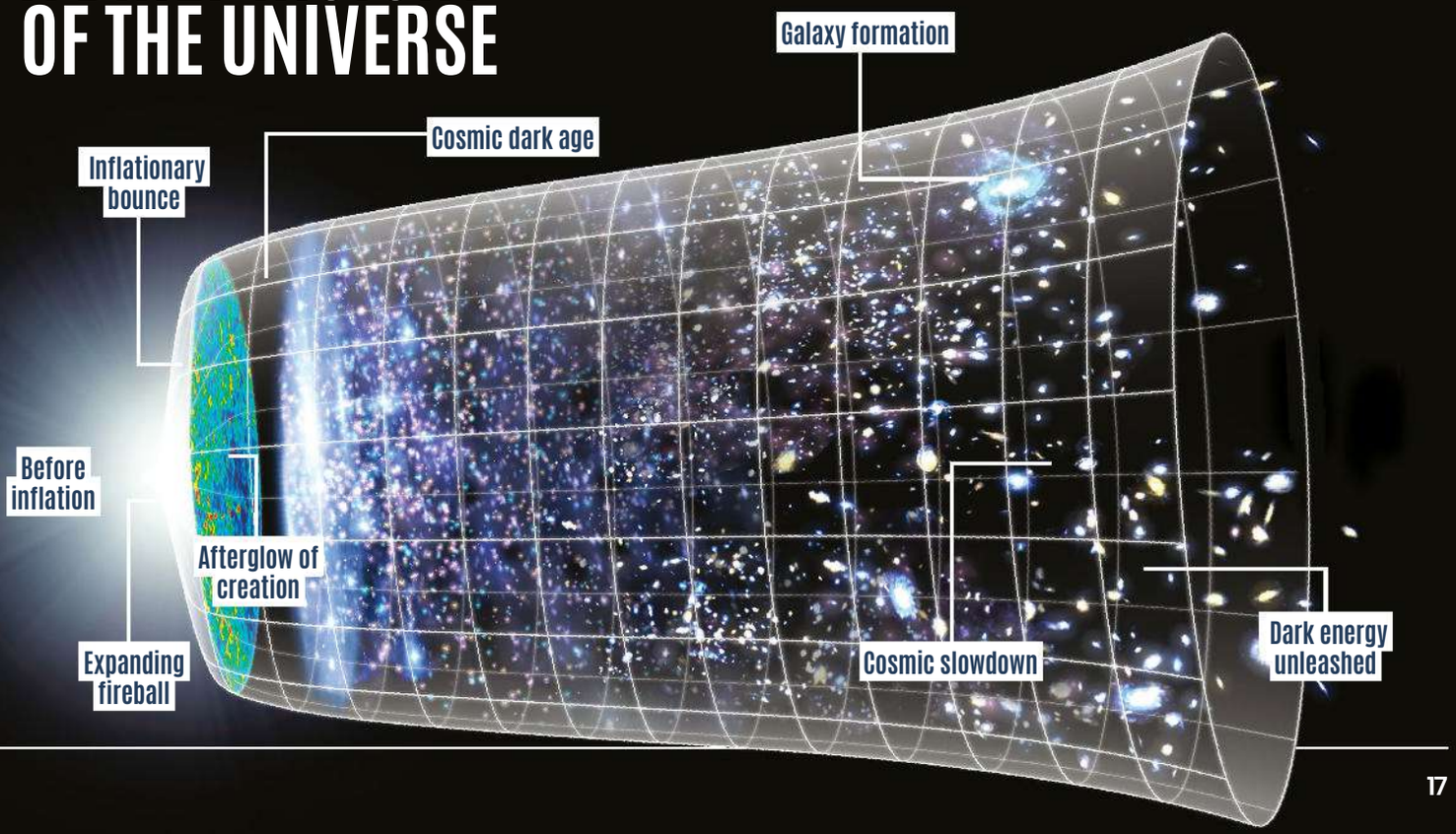
"Dark energy causes the expansion of our universe to accelerate," Burkmar and Bruni say. "It has negative pressure, and therefore can make gravity repulsive, rather than attractive. In general, anything that has a negative enough pressure plays the role of a dark energy, and can evolve with time. The



A A simulation shows visible matter (yellow) being drawn by gravity towards concentrations of dark matter seeded in the early universe.

B Temperature differences in the cosmic microwave background radiation are the result of tiny density variations in the primordial universe, magnified by inflation.

A BRIEF HISTORY OF THE UNIVERSE



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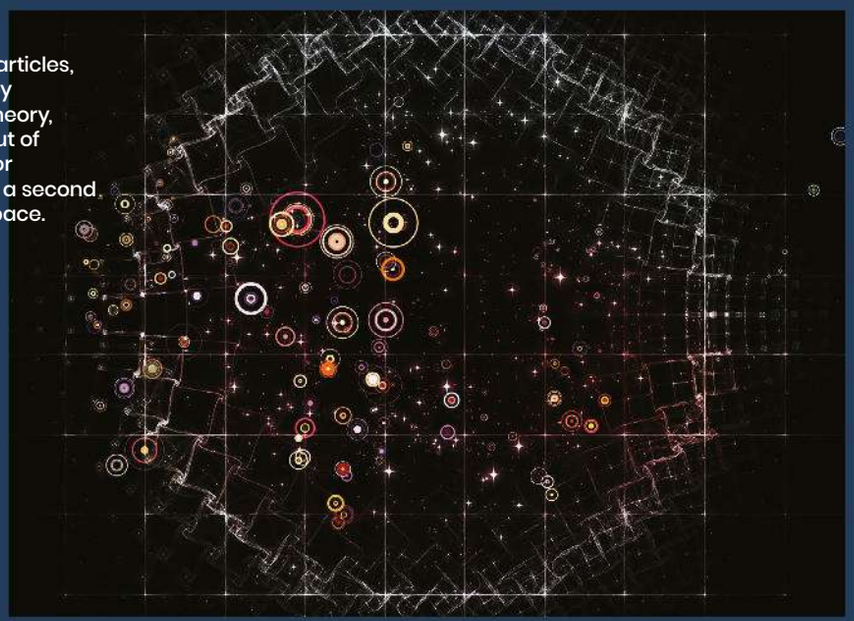
WHAT CAUSED THE BIRTH OF THE UNIVERSE?

Many scenarios illustrate how our universe may have come into being

1 There was nothing

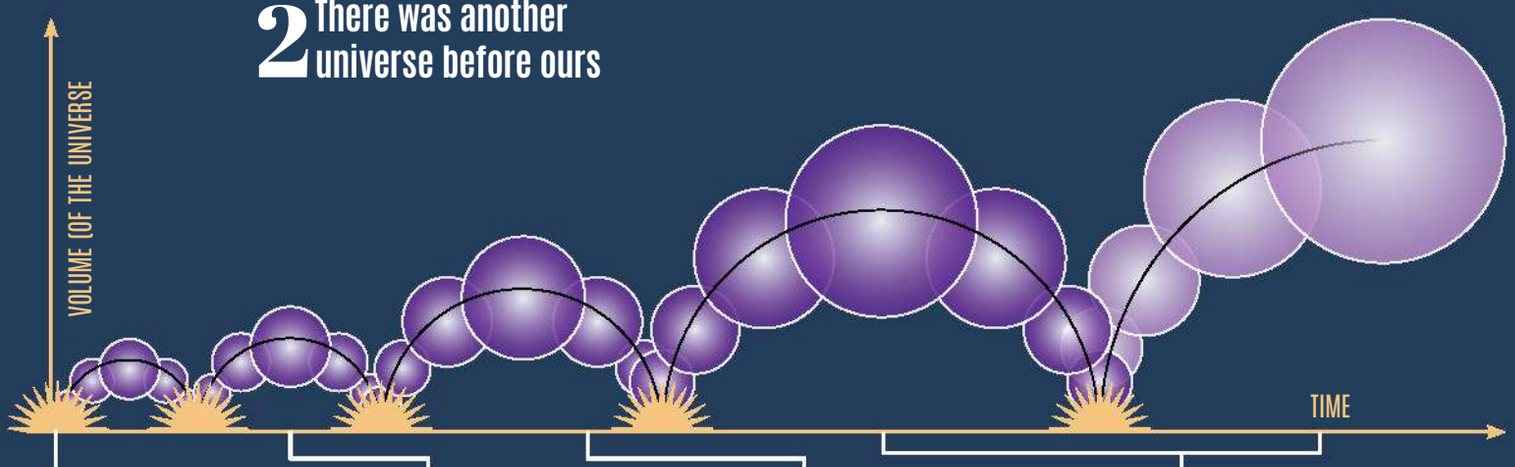
Strictly speaking, no scientist believes that our universe started from literally nothing. There always has to be something to cause another action to occur. However, many cosmologists are not yet convinced that there was anything before the Big Bang. Lawrence Krauss is one such scientist and he's developed a theory of 'quantum nothingness' from which the universe could have originated.

The theory involves so-called 'virtual particles', which flit in and out of existence for fractions of a second in empty space. They are predicted by quantum theory and their effects can be observed. Krauss says that if you remove virtual particles from a region of space it still has an energy density – but it shouldn't. It's from this form of 'nothing' that our universe could've started.



Virtual particles, predicted by quantum theory, flit in and out of existence for fractions of a second in empty space.

2 There was another universe before ours



Big Bang and expansion

In the cyclic model, a universe may have a true origin as normal and go through an inflation and expansion phase.

Everything now stalls

In a cyclic universe the cosmos may expand to a point and then stall. This may happen from the gravitational effect of matter.

Universe in reverse

Gravity takes over and the universe now contracts, with galaxies moving towards one another instead of further away.

Big bounce and next phase

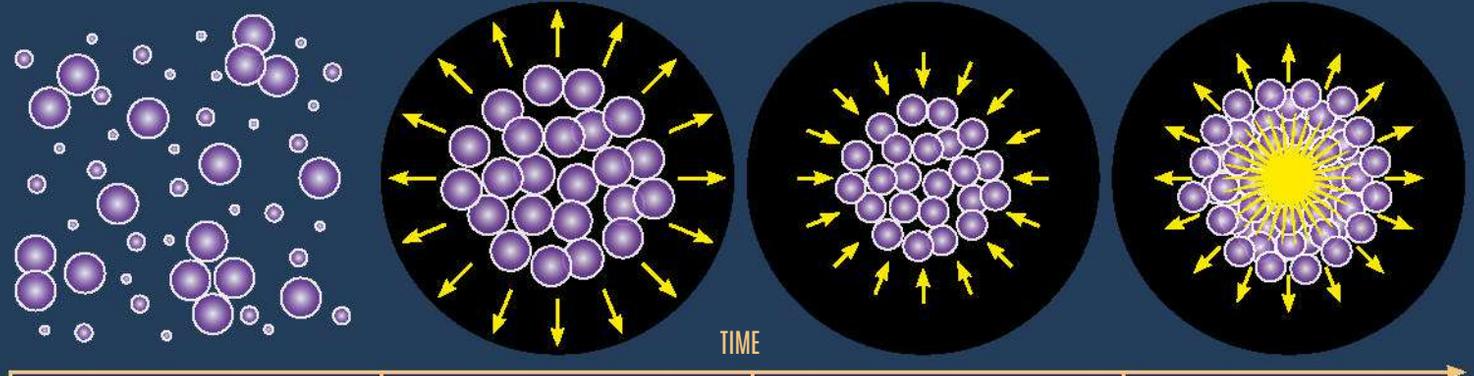
Inevitably, the universe can only contract so far. A 'big bounce' initiates the next expansion phase. The process continues.

similarity between inflation and the current dark-energy-dominated period is that the expansion of the universe is accelerating in both cases."

Inspired by this similarity, the cosmologists set out to look at how the universe might evolve in a situation where the pressure from dark energy could change dramatically at different points in cosmic evolution. "Our research involved analysing the consequences of Einstein's [general relativity] equations in the presence of a dark energy that can evolve between a maximum and a minimum value," they explain. "During the contraction of the universe, the dark energy increases... so the size of the universe reaches its minimum and bounces. Then the universe expands, and the dark energy decreases towards its minimum. When the dark energy is close to its maximum or minimum, the universe accelerates [growing or shrinking rapidly]. Therefore, in our model, this dark energy explains both the bounce [of inflation], and the observed accelerated expansion today."

Bruni and Burkmar's work stands in contrast to other models that treat inflation as a separate phenomenon from dark energy and require space to have new exotic

3 It's always been there



An empty infinite universe
In this scenario, the universe has existed forever and was nearly empty for that time. Then gravity took over and matter started to clump together.

Expanding internal region
The density of matter is such in some regions that it forms an incredibly massive black hole, the internal region of which experiences an expansion.

A big crunch
Inside the huge black hole, matter again collapses under the intense gravity and increases in density up to a limit imposed by physics.

The Big Bang
When it can't stand any more, quantum fluctuations cause the matter to expand outwards in a typical Big Bang scenario within its black hole universe.

It is one universe of many

4 Eternal inflation theory was proposed in 1983 by physicist Paul Steinhardt as an extension of the cosmic inflation and Big Bang theories. Alan Guth, Andrei Linde and Steinhardt originally developed cosmic inflation theory to explain some problems with the Big Bang model, and it involved an exponential but rapid expansion of our universe.

The cause of cosmic inflation still remains somewhat vague, but for eternal inflation, Guth proposed in 2007 the existence of a 'false vacuum' or region of space with a positive energy density – similar to expanding bubbles forming in a boiling liquid. In this manner, certain regions of space-time (or 'universes') would be affected by their own form of cosmic inflation, before the positive vacuum moved on to another region.

As of yet, this scenario lacks evidence, but if true, then our universe could exist as a nodule on another universe as part of a 'multiverse'.

Another theory suggests that our universe is one of many that exist parallel to one another and is part of a multiverse.

© Alamy

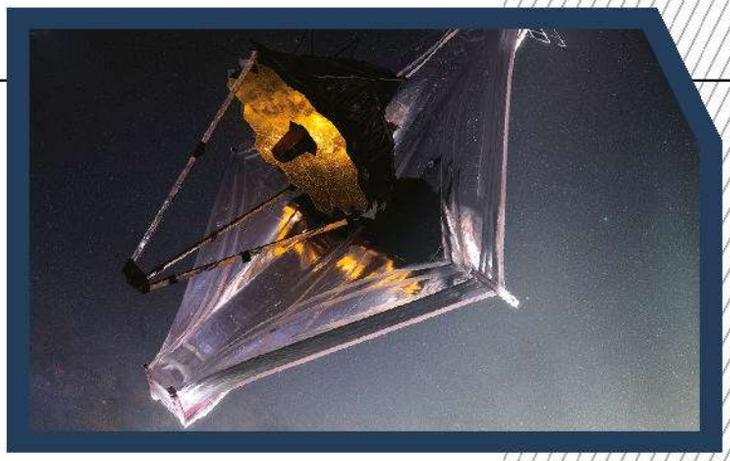
properties in order to explain how it was triggered and why it went away. What's more, if inflation did not mark a beginning but a 'bounce', it opens up the possibility that our universe is just the latest iteration in a potentially infinite series extending to the past and future. Today's cosmos emerged from a previous bounce, and one day the changing influence of dark energy will reverse its current expansion, drawing everything back to another bounce in the far future. It's an intriguing idea – though there's one important limitation; in order for the bounce to work, space itself has to have that 'positive curvature' that Bruni and Burkmar discuss. That is, there must be enough mass and energy within the universe to eventually bring the contraction to a halt – something that is far from certain.

But what would conditions within the 'bounce' itself be like? Bruni and Burkmar emphasise that it still has to take place at a point where the universe is extremely compact and very, very hot: "[It] necessarily has to occur at a high enough energy that all the standard physical processes that

take place in the cosmic evolution can happen," they elaborate. "The observed abundances of light elements in the universe are well explained by so-called 'big-bang nucleosynthesis', but this doesn't need a singularity – just a 'big bang' in the sense of a very high energy state where matter is hot enough for fusion of protons and neutrons into lithium, helium and so on. As for inflation, the proof in the pudding would be to work out if the accelerated phase around the bounce is long enough to produce the initial seeds for the formation of structures in the universe. This probably means that the bounce has to occur at really extreme energies."

If the universe does indeed contract back to a superdense, superhot 'big crunch' before each bounce, then it would erase almost every trace of its previous iteration, as matter disintegrated and transformed back into pure energy in accordance with Einstein's famous equation E=mc^2. Indeed, the pair's calculations suggest that allowing matter or even radiation to persist during the period of reversal 'spoils' the bounce – everything must become dark energy. One thing that might survive, however, are black holes from the previous universe.

Although this 'bouncing' universe model offers a clever explanation for inflation by tying it to today's dark energy, Bruni emphasises that it doesn't attempt to explain the origin of the universe. "Inflation doesn't provide a solution for the beginning – but it leaves open the question of what happened before." It's likely to remain just that unless the pair can find concrete predictions that will allow it to be proved or disproved through observation. "The smoking gun for a bounce period could come from predicting the gravitational waves that should be produced after the bounce: these waves [telltale distortions in spacetime caused by superdense, rapidly changing objects] should be different from those produced during traditional Inflation. It would then be for future gravitational wave experiments to test the different possible bouncing models."



Every aspect of the Webb, from its mirror and instruments to its sunshield and orbit, is designed to capture faint infrared radiation from the most distant and ancient galaxies.

Giles Sparrow
Space science writer
The author of over 20 books, Giles holds a degree in astronomy and is an editor specialising in science and technology.

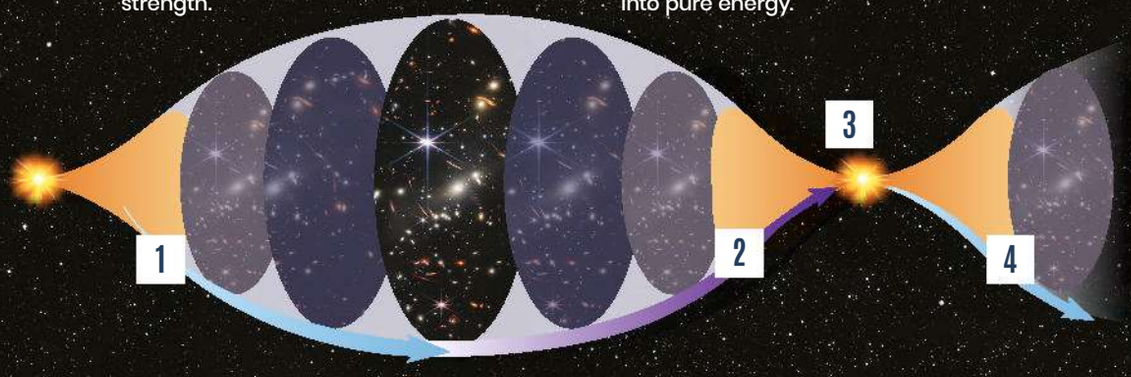
ARE WE IN A 'BOUNCING UNIVERSE'?

1 Inflation
Very early in the current universe, something drove the rapid expansion called inflation. The bouncing universe theory suggests this was the pressure of dark energy, which later diminished in strength.

2 Contracting universe
According to the theory, the strength and direction of dark energy can oscillate; in the far future, it could effectively reverse, causing space to contract.

3 Big Crunch
As the future universe grows smaller, the strength of dark energy increases rapidly. The universe becomes hot and dense once again, and matter is transformed back into pure energy.

4 A fresh start
Before space collapses to a singularity, the effect of dark energy reverses and drives a new burst of inflation – the universe is reborn.



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FOCUS ON

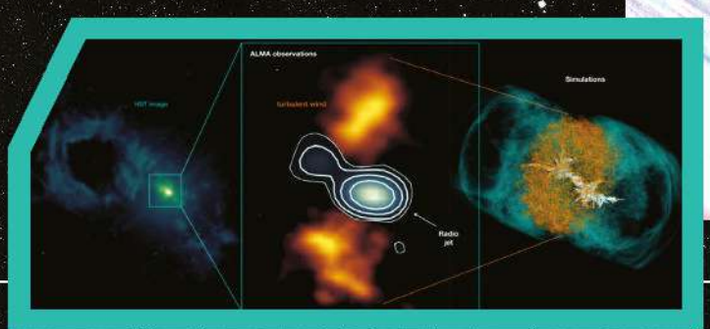
RELATIVISTIC JETS BUBBLING IN THE TEACUP GALAXY

Even low-power jets can help shape a galaxy, it just depends where they're headed

Reported by Briley Lewis

New research investigates how relativistic jets from a supermassive black hole have been shaping the Teacup Galaxy, giving it its iconic handle. Active galactic nuclei (AGN) are some of the most intense places in the universe, where supermassive black holes are gobbling up matter and spewing out jets that move at almost the speed of light. Astrophysicists know that these relativistic jets shape the galaxies they're in, stirring up and pushing out material as they shoot out from the central black hole. But not all jets are created equal – some are stronger and drastically change their surroundings by heating up the gas in their galaxies, stunting the galaxies' growth. Others are weaker, referred to as radio-quiet, but computer simulations suggest that they still have shockingly large effects and an ability to push around nearby gas. "It was previously believed that low-power jets had a negligible impact on the galaxy," said Christina Ramos Almeida, an astronomer at the Instituto de Astrofísica de Canarias (IAC) and co-researcher of the new study.

The team's new observations from the Atacama Large Millimeter/submillimeter Array (ALMA) show that at least in the Teacup Galaxy – a radio-quiet galaxy named for its appearance that lies about 1.3 billion light years from Earth – jets are moving, heating and accelerating the galaxy's gas. "Even in the case of radio-quiet galaxies, jets can redistribute and disrupt the surrounding gas, and this will have an impact on the galaxy's ability to form new stars," Almeida said. Much to the team's surprise, the biggest effects were actually perpendicular to the direction of the jets instead of head-on. "This is caused by the shocks induced by the jet-driven bubble, which heats up and blows the gas," said lead scientist and IAC astronomer Anelise Audibert. It turns out that even low-power jets have an impact – it just depends where they're headed.



Artist's impression of an AGN

The compact radio jet in the centre of the Teacup Galaxy blows a lateral turbulent wind in the cold, dense gas

© Getty; HST/ALMA

SPACE FARMING

Future astronauts will need to grow their own plants in artificial environments if they are to survive missions far from Earth

1 Hydroponics
Plants will be unable to grow in lunar or Martian soil, so an artificial hydroponics system will be needed to provide water and nutrients to enable the plants to flourish.

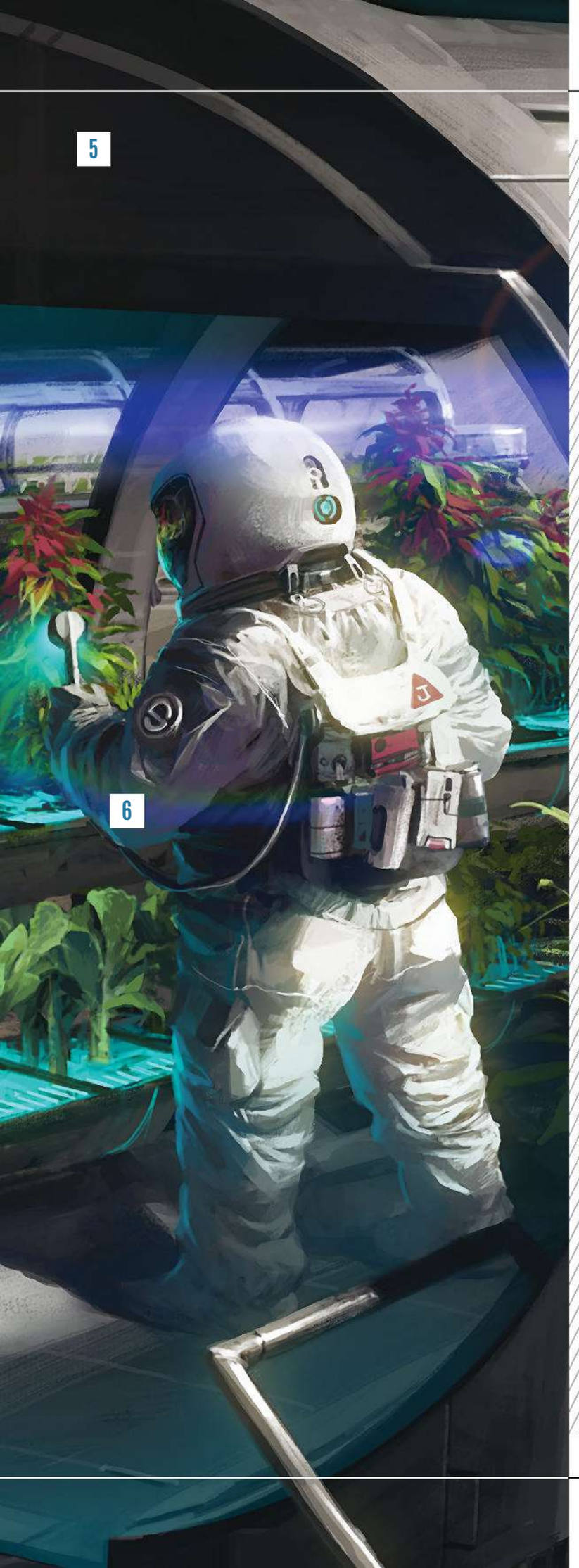
2 Ready meals
Some plans envision plant-bearing habitats being launched to the Moon ahead of astronauts. They would be tended to by robots until astronauts arrive.

3 Sunlight
Plants in space will grow like they do on Earth, using sunlight and carbon dioxide. If the habitat is exposed like this, the plants will easily be able to gather sunlight.

4 Life support
As well as providing food, plants consume carbon dioxide and give off oxygen. Therefore, they could be a substitute for mechanical life support systems.

5 Protection
To protect plants from radiation on the Moon it may be necessary to bury habitats in lunar soil. But Mars' atmosphere could possibly provide enough protection.

6 Self-sustaining
By enabling astronauts to grow their own food, they will be able to rely less on cargo ships from Earth, although they may still need some visits for other life-essential things.



For future human missions beyond Earth orbit, out of reach of cargo spacecraft, it will likely be necessary for astronauts to grow their own food in order to survive. To achieve such self-sustainability they will need to grow food on their spacecraft, and perhaps even a future lunar base or other such habitat will utilise space farming to ensure the survival of astronauts.

If you think space farming is something from the distant future, however, you'd be wrong. On board the International Space Station (ISS), astronauts and cosmonauts alike have been testing out the feasibility of growing plants for over a decade. The USA-based Space Dynamics Laboratory, in partnership with the Russian Institute of Biomedical Problems, developed a low-cost growth chamber known as Lada to operate on the ISS. It has grown a number of things including wheat and peas, and has so far proven that plants can grow in space with no noticeable side effects.

Research such as this is imperative for any future space farming endeavours. Growing plants on the Moon or Mars without soil (known as hydroponics) is certainly not out of the question, provided the plants were kept in a habitable environment like the Lada experiment on the ISS. Based on experiments so far, space farming shouldn't prove to be too difficult; growing plants in artificial environments is likely to be a feature of any future manned missions beyond Earth orbit.

One of the challenges of space farming is that any out-of-this-world farms will have less gravity than on Earth. Based on ISS experiments, however, it's clear that plants are able to grow even in weightlessness as they can support themselves. There will also be limited space in which they can grow, so space farms will need to be designed with this in mind.

Space farms will be useful not only for food but also for life support. Plants can recycle carbon dioxide into oxygen, something that is currently performed by machines. This could enable space colonies to rely less on machinery and therefore reduce the amount of cargo and equipment they need to carry. By also supplying astronauts with food on the way, astronauts will not need to take a huge amount of meals with them (and therefore more cargo), instead relying on sustenance from plants. This has led some experts to speculate that the first visitors on Mars will be vegetarians, as bringing unrenewable meat along for the ride will take up valuable cargo space.

Whatever shape or form future space farms take, you can be sure that they will be an integral part of space exploration. With proposed missions to Mars lasting at least a year, it's unfeasible to imagine that such a mission would be successful without the renewable food source provided by space farms.

"Space farms will be useful not only for food but also for life support"

© Jay Wong

BIO+

Margot Shetterly

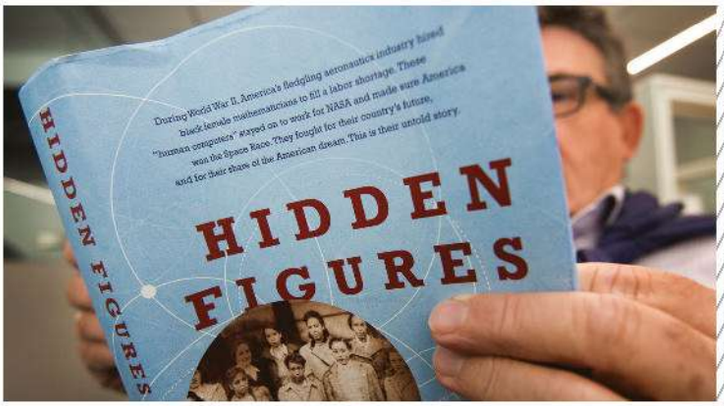
Growing up in Hampton, Virginia, Shetterly took for granted that scientists and mathematicians would as often as not be female and non-white. After leaving the town, home to NASA's Langley Research Center, she realised that was far from the case. Shetterly's book, *Hidden Figures*, follows the Black women at Langley who were hired as 'computers', scratching out complex computations for the centre's aeronautical and rocket research.

The making of *Hidden Figures*

"I wrote so many drafts of this book"

All About Space speaks with Margot Shetterly about her book, *Hidden Figures*, the challenges of uncovering that history and why human computers are suddenly looming large in the public consciousness

Interviewed by Sarah Lewin



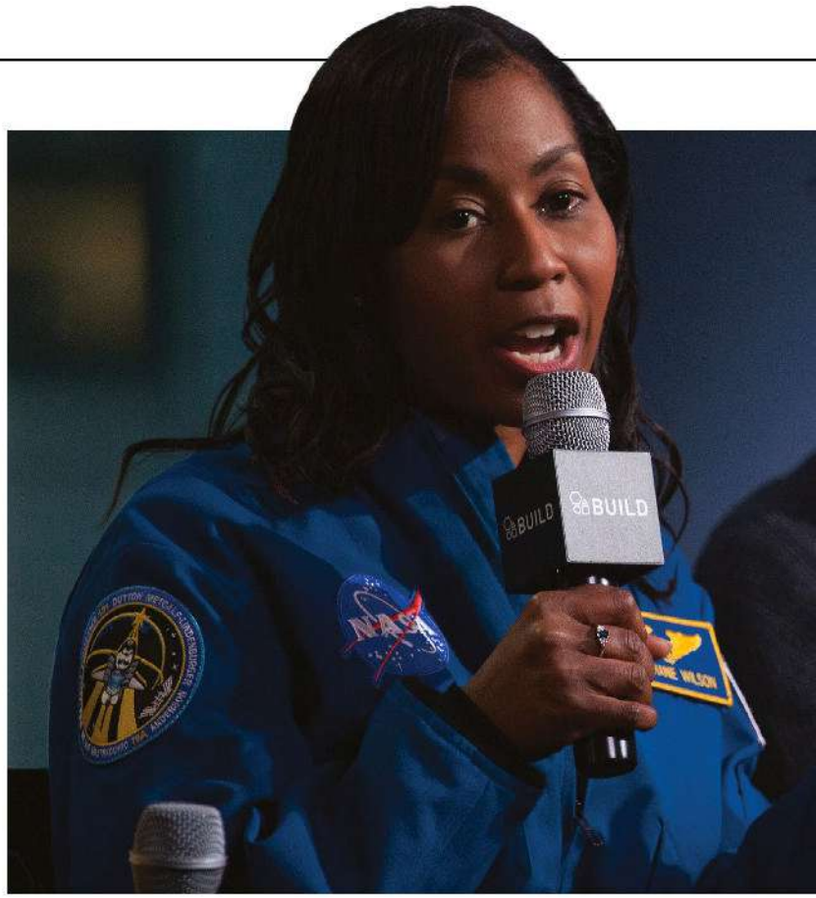
Shetterly's book was published in 2016, but she began work on it in 2010

Was it challenging to track down the history of Langley's woman computers?
One [challenge] was trying to figure out exactly how the segregated group of black women came to Langley. Trying to track down when it happened, who was there, where they were originally sent to work, because they had to be in a segregated office. What I concluded is that it was not quite a handshake deal, but that everyone kind of quietly agreed this was going to happen, and it happened. It wasn't something that happens with a lot of fanfare. Tracking that down, it was really like there's an article in the newspaper *The Norfolk Journal and Guide*, which announced the first woman going there, and then all of a sudden their names started appearing in the Langley newsletter.

How did you choose which women to focus on?
You couldn't tell this as a single person's story. This is the story of broad success of women overall, and African-American women specifically, in a job category that it's simply assumed they don't exist. During a time of Jim Crow segregation, during a time when women frequently weren't even allowed to have credit cards in their own names, here were these women – large numbers of women – doing very high-level mathematical work at one of the highest scientific institutions in the world at that time. I wanted it to be a story that could show that broad group, but at the same time, in order to make it interesting you have to choose the people with the most compelling stories.

Who did you follow?
Dorothy Vaughan, Mary Jackson, Katherine Johnson and Christine Darden – each of them represented a certain slice of the narrative in terms of the development of women in the workplace over that time. They each faced different things. They all had different kinds of work – we were able to look at both the aeronautical work and the space work that the centre was doing,

Johnson checked the calculations that took John Glenn into space



and they all had different connections to the larger world. Dorothy Vaughan, who was the first Black supervisor at what became NASA by being made a section head of the segregated group of black women, had also worked as a teacher at one of the high schools that became a fundamental part of the Brown v. the Board of Education Supreme Court case. Here's this woman, she's connected to two of the most amazing parts of the 20th century. Mary Jackson was from Hampton and had this family history that really came out of the Civil War and Reconstruction. Each of the women, in addition to the work they did and in addition to the compelling personal stories, ended their careers at the research centre, so I was able to follow them out to the ends of their careers. They also had some significant links to the larger world: the idea that Katherine Johnson worked in the antique shop at the Greenbriar, which is this old war emblem, I couldn't believe it.

Can you talk about how you incorporated scientific details into the story?

I'm not a scientist or a mathematician, so it really did take a lot of self-study and reading research reports and reading textbooks and looking at videos on YouTube, which were very helpful, to put together the work that the people did. I think I had to have a greater level of technical command of the topics than what actually made it into the book. This is a book for the general audience, and most general readers are probably not that interested in Reynolds numbers or differential equations. At the same time, there were other parts, for example really understanding what they were doing with the wind tunnels and what makes things fly. It's interesting, because you're asking yourself this question that you take for granted. You get on a plane, it moves through the air, it lands safely, you don't think about it. And so having to actually slow down and think about the physics and the maths and the understanding of the concept behind it was really enjoyable. I learned a lot. Even though I'd certainly not call this a technical book, I've enjoyed talking with lots of the ex-NASA people about this stuff, but it had to be put into a form that the general reader wouldn't get stumped or just put the book down because they thought it was too much.

Was your research and writing process one of writing as much as possible and then editing things out?

I wrote so many drafts of this book. I think that a lot of the early drafts were really a way for me to suss out what really happened. There were so many things that I needed to understand – the kind of work that was done at Langley, the kind of research. I spent a lot of time going through the NASA technical report server. Taxpayer dollars are so well spent that anyone with a computer can go into the database and they can find the research reports from NASA, going back to the founding of the agency. You can literally see the progression of aeronautical research and development from the 1920s until today. It's remarkable. There were so many great resources that allowed me to put too much meat on the bones and then carve back so that what was always leading was the women and their stories and their perspectives, with the history and the science being pulled by their stories.

My obligation as a writer is to try and uncover all of the aspects of the history, put all of those things in the footnotes and make sure everything is really documented. That was something that was also really important to me from the very beginning: not just writing the story, but making sure that I had left as much as possible a comprehensive trail of where to find this information. There were a lot of times when I'd dig into boxes at the National Archive, and instead of those lovely preserving archive boxes it'd be some cardboard box that had obviously gotten wet, and nobody had looked at the

© Getty

papers since they'd got thrown in there in 1946 or something. My publisher has given me permission to publish notes and make them available on my website, and so I'm trying to figure out when I can actually get that done.

What do you hope people get out of this book?
I really hope that this goes a long way to helping all of us change our perception about what a scientist looks like, what a mathematician looks like, who's capable of doing that work at the highest level. This is a discussion that we're having at a very high level and across many different disciplines: education, the private sector and government. How do we fill the need for technology workers, people who have computer skills and maths and science skills? How do we get a more diverse science workforce? These are all issues – I'd look at these documents that were from the 1950s, 1960s and 1970s, and you'd swear they were written two weeks ago, because the issues are the same.

The other thing is, even though it's a story that's being told from the point of view of African-American women, I hope people see this as really a very American story. It's the Space Race, it's the Cold War, it's the women's movement, the civil rights movement, World War II – all of these grand, sweeping changes and upheavals and forces that defined the 20th century that we've all studied in school and we all still talk about, and we're all still fighting about in a lot of ways, and it's attached to this group of African-American women. So just because the protagonist is different doesn't mean that it's less of an American history. I do believe that it is possible to see this as a great, sweeping American epic, which is one of my favourite things.

"Each represented a certain slice of the narrative in terms of the development of women in the workplace"

Why are there so many stories about early NASA computers coming out right now?
That is a great question. I don't know why. Perhaps it is because a lot of these women are from the World War II generation and they are passing away. People are interested in capturing these stories before it really is too late. I think perhaps it's because there's an urgency to collect the stories of people from this generation. And I think also it's because this whole thing of women in STEM [science, technology, engineering and mathematics], and minorities in STEM, is so top-of-mind right now.

There are lots of examples over history of women working as mathematicians and really providing the raw calculations that allowed us to fuel stupendous growth in technology and scientific knowledge. A lot of this came out of the needs of World War II, then the Cold War, then the Space Race – does it take a national emergency for us to tap into all of the talent? Is there a way to do it without precipitating a national emergency? I don't know.

Are you considering any follow-up book on this part of NASA history?
I actually have two book ideas that came out of this that don't have to do with space, but that sort of... I kind of see this as a mid-century African-American trilogy. They came from the same period of time and ask a lot of similar questions about social mobility and work. But I do think that there are – you could probably write more books just on the Langley research centre.

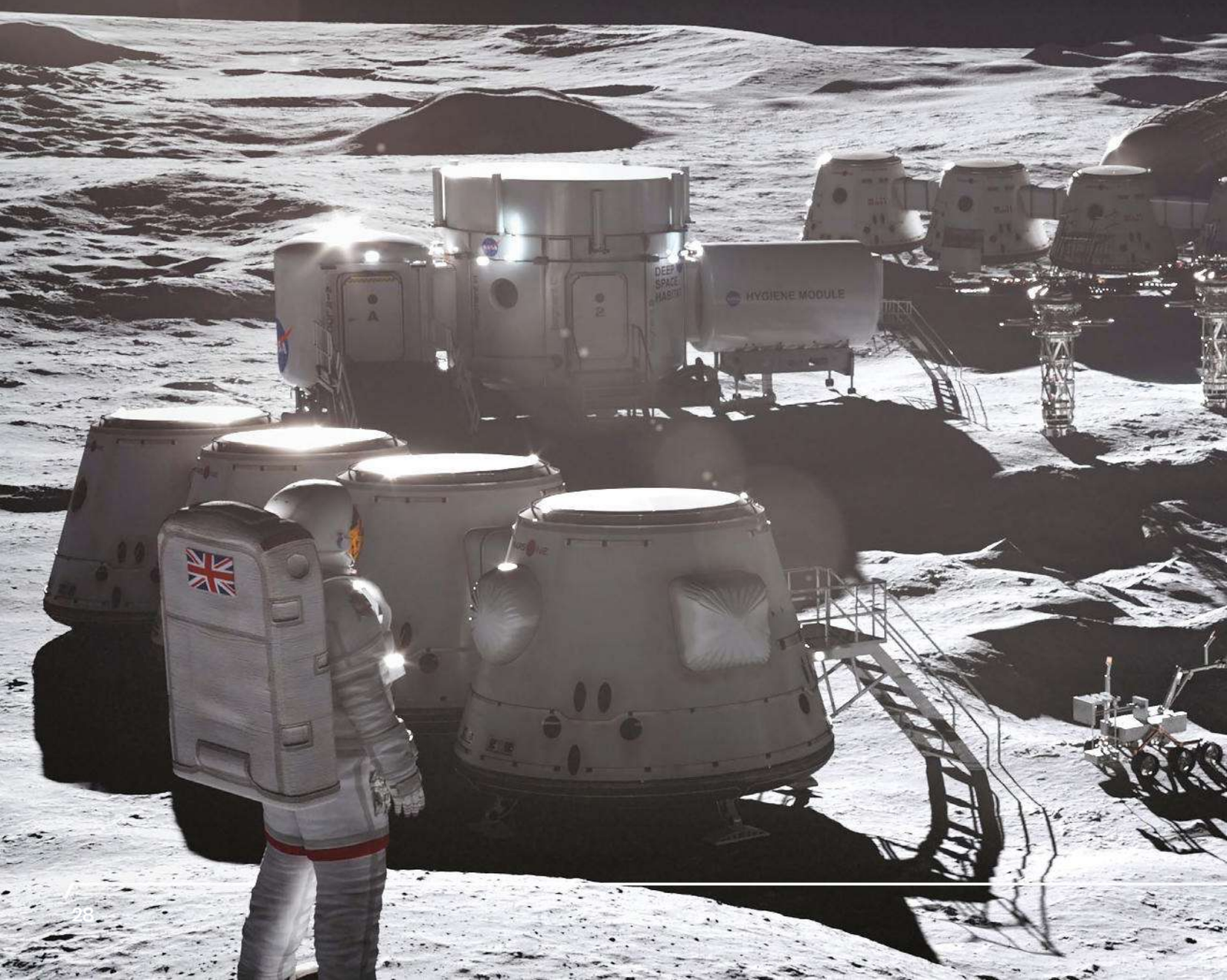
NASA astronaut Stephanie Wilson and Shetterly at Build Presents

Shetterly at a special screening of the film based on her book

ROLLS-ROYCE ON THE MOON

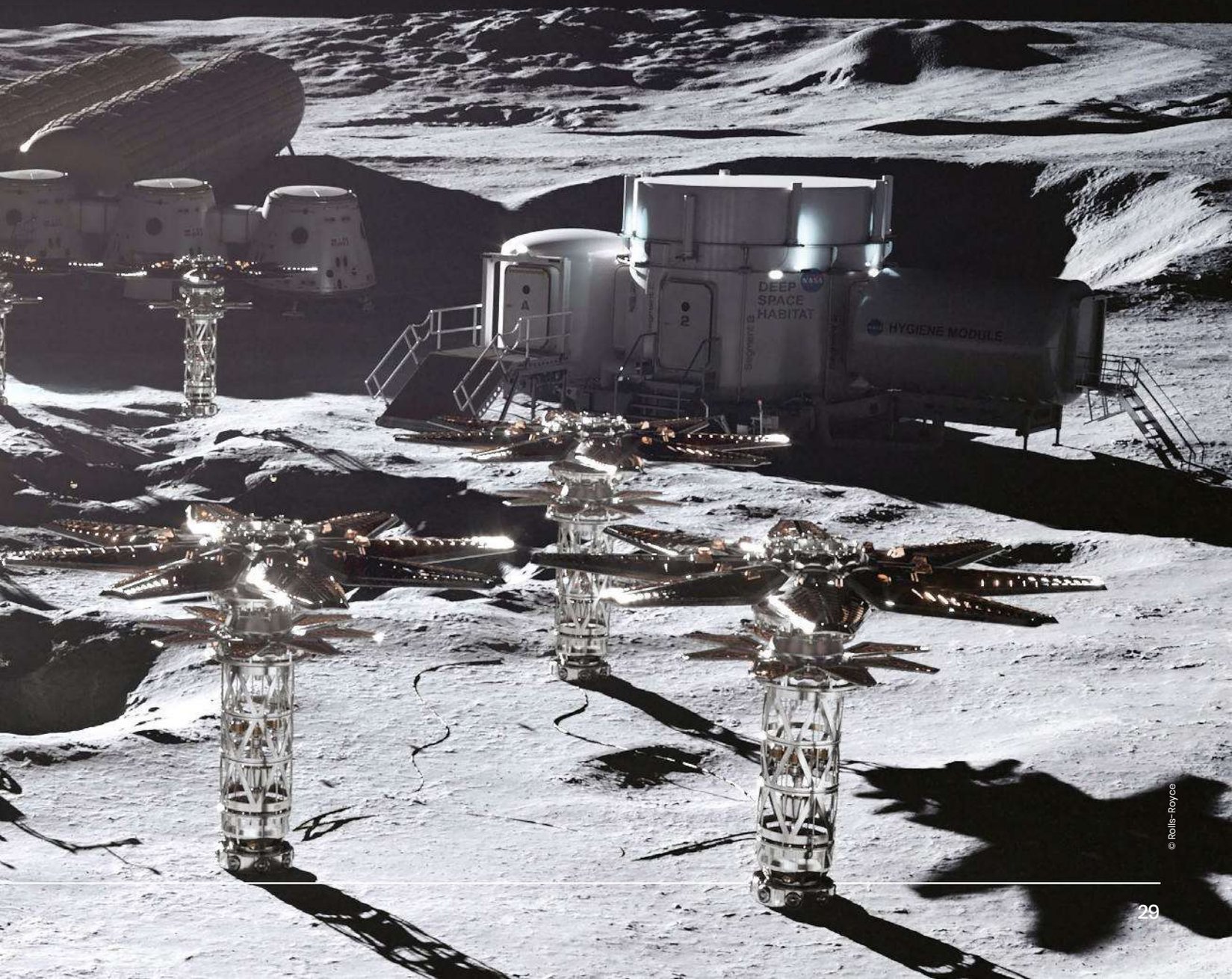
With the British car manufacturer shooting for the lunar surface, humankind could finally be ready to return by the 2030s

Reported by Nigel Watson



After a lull of over 50 years, the number of projects to take humans back to the Moon is escalating at a fast rate. This time, instead of one-off landing missions, these will be the first steps in building long-term Moon bases. An essential part of any Moon base will be a continuous and reliable source of power to run essential life-support systems, communications, lunar vehicles, workshops and scientific laboratories. A small nuclear reactor could meet many of these demands, and in 2022 the UK Space Agency funded a £249,000 ($310,510) study into the feasibility of designing and building one by Rolls-Royce. The agency has now provided a further £2.9 million ($3.6 million) of funding to deliver an initial demonstration of a UK lunar modular nuclear reactor. "Space exploration is the ultimate laboratory for so many of the transformational technologies we need on Earth: from materials to robotics, nutrition, clean technology and much more," says Minister of State in the Department for Science, Innovation and Technology George Freeman. "As we prepare to see humans return to the Moon for the first time in more than 50 years, we're backing exciting research like this lunar modular reactor with Rolls-Royce to pioneer new power sources for a lunar base. Partnerships like this between British industry, the UK Space Agency and government are helping create jobs across our space technology sector and help ensure the UK continues to be a major force in frontier science."

The concept of creating permanent bases on the Moon goes back to the days of the Space Race. In 1959 the US Army's Project Horizon proposed a military Moon base, and from 1962 to 1974 the Soviet Union secretly worked on Project Zvezda, which aimed at building an ambitious modular base. Now, with improvements in technology, such ambitious plans are much more obtainable, and China, Russia, Europe and the US plan to help turn such concepts into reality.



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The umbrella-like structure of a small Rolls-Royce nuclear reactor on the Moon

The prototype Kilopower power unit before it was sent for testing in 2018

Artistic representation of the Artemis base on the lunar south pole

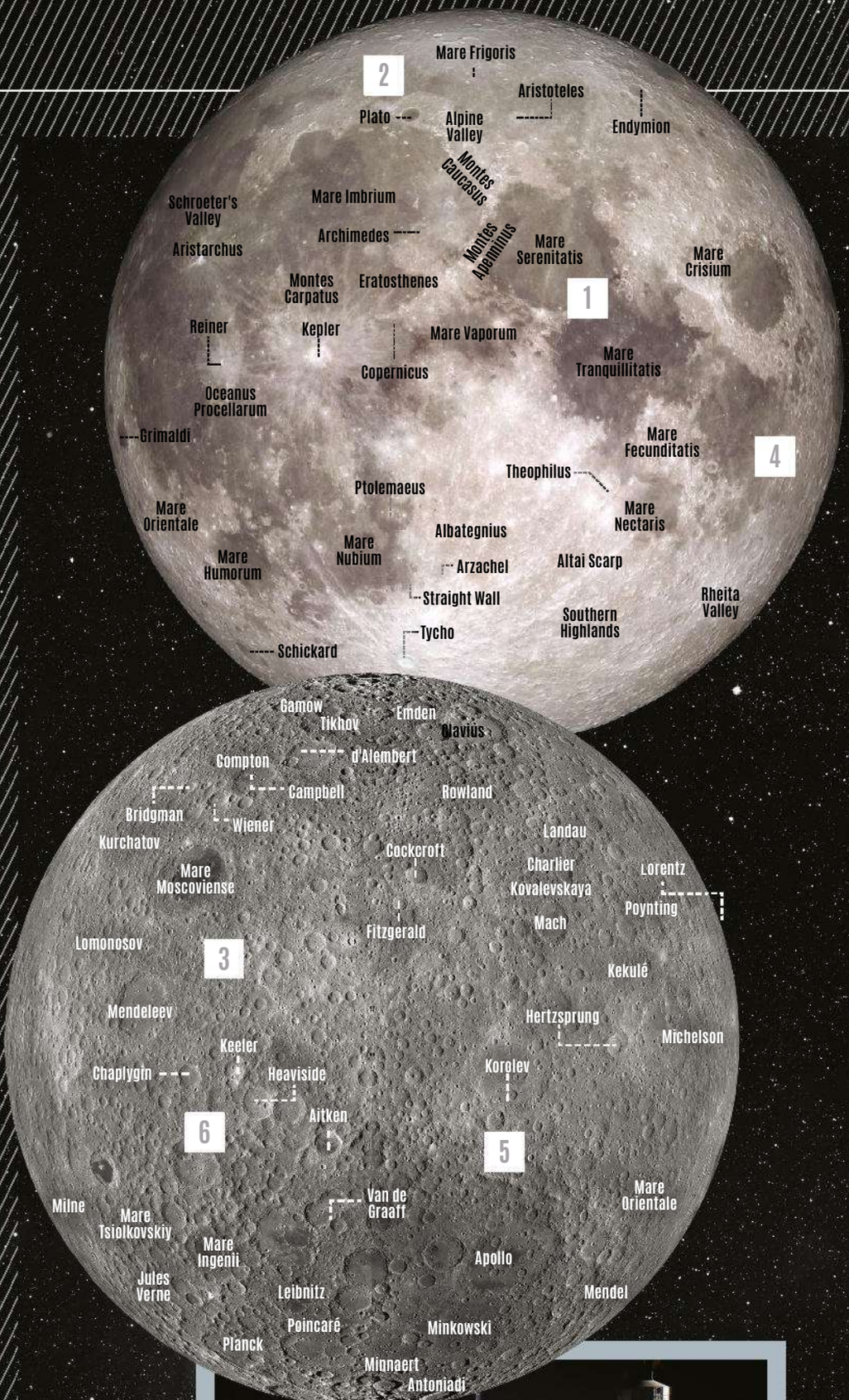
NASA's Lunar Surface Innovation Initiative (LSII) works to identify the technologies needed to create a Moon base and has a surface power focus group that concentrates on the power systems that are best for sustaining power through the lunar day and night. Most of the Moon base concepts usually show fields of solar panels to provide power, but their electronics would be vulnerable to damaging radiation exposure and temperatures of up to 126.7 degrees Celsius (260 degrees Fahrenheit). Work is still ongoing to solve these problems, but an alternative solution is to use nuclear power, which could dramatically increase the duration and sustainability of lunar colonies. In a European Space Agency (ESA) study called Moon Village: Conceptual Design of a Lunar Habitat, dated September 2020, it agreed that a nuclear fission power source is "a lighter and more compact option than a solar power plant. It would also have the advantage that its development would be applicable to non-polar lunar applications, providing wider mission flexibility. On this basis, the nuclear fission option is selected as the baseline assumption."

The demonstration of the viability of a small modular reactor was conducted by NASA and the US Department of Energy in 2018 by the Kilopower team. "We put the system through its paces. We understand the reactor very well, and this test proved that the system works the way we designed it to work. No matter what environment we expose it to, the reactor performs very well," says Marc Gibson, the lead Kilopower engineer at NASA's Glenn Research Center. It consists of a thermal neutron-type reactor that has a solid cast uranium-235 reactor core the size of kitchen towel roll, surrounded by passive sodium pipes that transfer the heat generated by the splitting of the nucleus of an atom into two lighter and smaller nuclei. This heat is conducted to Stirling engines that drive a linear electric generator.

Called the Kilopower Reactor Using Stirling TechnologY (KRUSTY), it showed it could produce up to ten kilowatts of electricity over a ten-year period. For the Moon Village concept it was estimated that to power a pressurised 15.5-metre (50.8-foot) tall, 10.5-metre (34.4-foot) diameter habitat for human occupation would need 57 kilowatts during daytime and 60 kilowatts during nighttime. You would need to link up six KRUSTY power units of this type or scale them up to supply more power in one unit. "Kilopower gives us the ability to do much higher power missions and explore the shadowed craters of the Moon," adds Gibson. "When we start sending astronauts for long stays on the Moon and to other planets, that's going to require a new class of power that we've never needed before."

Having established that a small nuclear reactor is a viable option, many countries are now developing the technology. The Italian Space Agency is designing a compact, light, reliable and safe reactor for lunar, Martian and deep-space exploration. "The basic principles for the design of the reactor are modularity, easy expansion of available power and the redundancy of essential systems to guarantee maximum reactor safety," says Mariano Tarantino of the Italian National Agency for New Technologies, Energy and Sustainable Economic Development. Meanwhile, NASA and the US Department of Energy have selected three design concept proposals for a fission-based surface power system. Three companies – Lockheed Martin, Westinghouse and IX – each received $5 million (£4 million) of funding to complete the projects by the end of this decade and be part of NASA's Artemis project.

Not wanting to be left behind in the race to produce a small nuclear reactor, the UK is backing Rolls-Royce to produce a power system that could provide continuous power regardless of location, available sunlight and other environmental conditions, all in a relatively compact and lightweight unit. It's planned to be ready to send to the Moon by 2029. Dr Paul Bate, chief executive of the UK Space Agency, says that "this innovative research by Rolls-Royce could lay the groundwork for powering continuous human



TWO SIDES TO THE MOON

We can't see the far side from Earth, but the lunar faces are impressively different

1 Lunar plains

Visible with the naked eye, the lunar maria – Latin for 'seas' – are dark patches. They are soldified pools of ancient lava.

2 The highlands

Lunar highlands have been dated at 4.4 billion years and are unlikely to have formed from tectonic activity.

3 Heavily cratered

Compared to the near side, the Moon's far side is incredibly rugged with next to no dark, flat lunar maria.

4 Impact craters

Made by asteroids and comets crashing into its surface, there are roughly 300,000 craters wider than one kilometre (0.6 miles) on the near side alone.

5 Not-so-dark side

Often incorrectly called the 'dark side of the Moon', the far side experiences two weeks of sunlight.

6 Seeing the far side

From Earth, it's possible to observe a small portion of the far side during libration, when up to nine per cent is visible.

"When we start sending astronauts for long stays, that's going to require a new class of power"

Marc Gibson

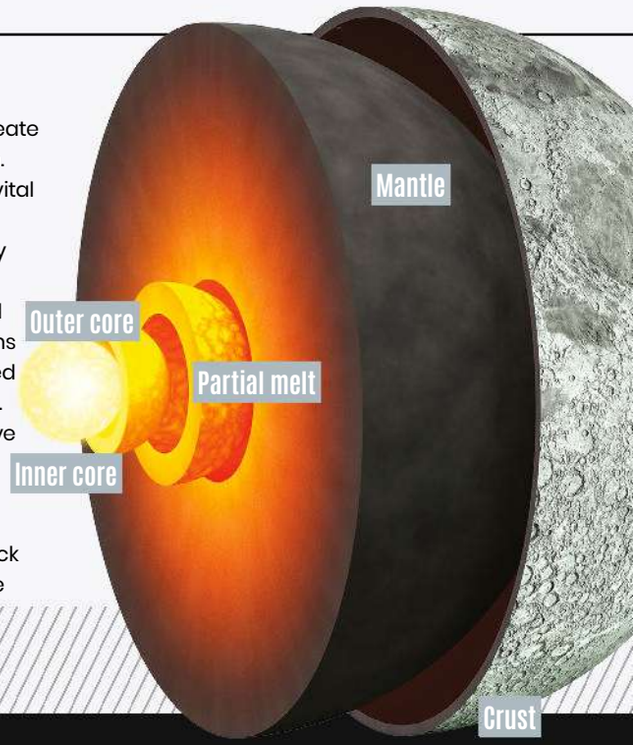
© NASA/Pete Reyes

presence on the Moon while enhancing the wider UK space sector, creating jobs and generating further investment."

Rolls-Royce will be working alongside a variety of collaborators including the University of Oxford, University of Bangor, University of Brighton, the University of Sheffield's Advanced Manufacturing Research Centre (AMRC) and Nuclear AMRC. The funding means Rolls-Royce can further strengthen its knowledge of these complex systems, with a focus on three key features of the microreactor: the fuel used to generate heat, the method of heat transfer and technology to convert that heat into electricity. Regarding the type of fuel used, Bangor University is conducting research, led by Dr Phylis Makurunje, that will use additive manufacturing techniques to create nuclear-based fuels for space propulsion. Such stable nuclear fuel systems will be vital to enable deep-space missions.

The new processes being developed by scientists from Bangor's Nuclear Futures Institute will enable the development and manufacture of various fuel configurations and designs that cannot be easily realised by conventional manufacturing methods. The research will demonstrate the additive manufacturing of metallic and ceramic zirconium-containing nuclear fuels and assess their performance.

The harsh variations in temperature, lack of oxygen and high levels of radiation are



A BASE ON THE MOON

In the future, it's hoped that humanity will set up camp on the lunar surface

1 Humans in low gravity

Colonising the Moon's surface means that we can find out how the human body responds to long periods of low gravity – on the Moon it's one-sixth of Earth's.

2 Launching rockets

A lunar base could serve as a site for launching rockets, using fuel that has been locally manufactured, to Mars. It's easier to launch from the Moon since the gravity is lower.

3 Lunar bases

Bases on the surface would need to be protected from radiation and micrometeoroids. Building a Moon base inside a crater would provide some shielding.

4 Building an observatory

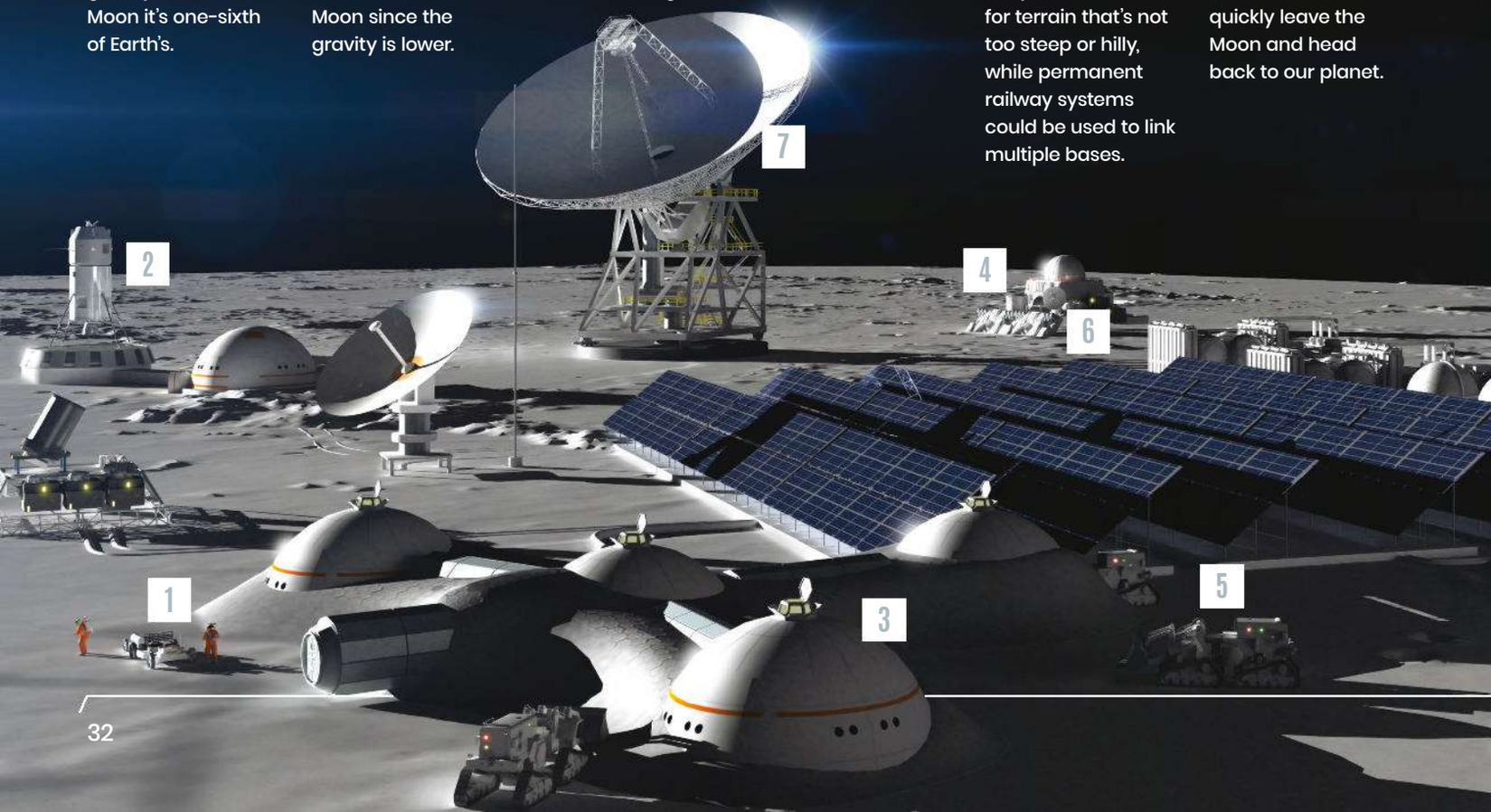
Making facilities for astronomical observations on the Moon from lunar materials would remove the need to launch them.

5 Transport on the Moon

The ability to transport cargo and people to and from modules and spacecraft would be essential on the Moon. Rovers are likely to be useful for terrain that's not too steep or hilly, while permanent railway systems could be used to link multiple bases.

6 In an emergency

A short transit time of three days, which astronauts could improve on, allows emergency supplies to quickly reach a Moon colony from Earth or allow a crew to quickly leave the Moon and head back to our planet.



just some of the things humans have to cope with on the Moon. Most base concepts show it's necessary to start with separate modular structures suitable for habitation and research that will have the ability to be expanded and improved, preferably with the resources available on the Moon.

The ESA has been working on a Moon Village concept since 2015. It's not allied to any specific nation but is run on similar principles to the International Space Station. China and NASA have expressed an interest in collaborating, but it's more a forum to develop ideas rather than a specific ESA program to actually build a Moon base. The Moon Village would consist of inflatable pods protected by hard outer shells that would provide living areas, workspaces and life-support systems. To make the village self-sufficient, water and oxygen would be extracted from permanently shadowed craters, and the lunar regolith could be utilised for use as a basic building material and for growing crops.

The Russian Roscosmos had a Lunny Poligon project that intended to build a base suitable for human habitation in the 2030s. This has been cancelled in favour of an International Lunar Research Station to be constructed in collaboration with China. Like Lunny Poligon, robot craft would initially deliver the cargo and build an infrastructure for human use and habitation in the 2030s. NASA's Artemis Base project is tipped to be the most likely to succeed, and it will use SpaceX's huge Starship Human Landing System. The first mission will send two astronauts to the lunar south pole in December 2025, and prior to that a small unpressurised Lunar Terrain Vehicle will be delivered to the landing area to enable the astronauts to take short exploratory journeys. The astronauts will travel to the Moon in the Orion spacecraft before transferring to the Starship, and there's another crewed Starship landing scheduled for September 2028. After that it's anticipated that there will be annual crewed missions, possibly using different types of landing craft.

In 2030 a Foundational Surface Habitat will be sent to provide the main quarters for up to four astronauts for up to 60 days. Such a camp would be used for exploration and research, and over time it would be expanded. It's also envisaged that a gaseous oxygen pipeline could be run to the Moon's south pole to transport oxygen extracted from the lunar regolith and water from lunar ice. The pipeline would be made robotically using regolith, and the oxygen would go to a storage or liquefaction plant near the base. Much of this work depends on a myriad of organisations and equipment supplied by a variety of companies, so how the base develops depends very much on the success of such projects as the Rolls-Royce reactor.

For the first astronauts, life on the base will be quite spartan and last for only a few weeks at best. Eventually, the use of available resources will make the base self-sustaining, and the expansion of living areas will make life a lot easier. It will be a slow process, but lessons learnt here will help plans to visit and establish bases on Mars and beyond. "Nuclear power presents transformative possibilities for space exploration, and the innovative study we are conducting with Rolls-Royce on this could help propel our next generation of astronauts into space faster and for longer, significantly increasing our knowledge of the universe," says Amanda Solloway, the UK's Parliamentary Under-Secretary for Science, Research and Innovation.

7 Lunar machines
With the round-trip communication delay to Earth being less than three seconds, it allows near-normal voice and video conversation and allows some kind of remote control of machines from our planet.

8 Moon farms
A lunar farm would be stationed at the lunar north pole, allowing for eight hours of sunlight per day during the local summer by rotating crops in and out of the sunlight. Beneficial temperatures, protection from radiation and insects needed for pollination would need to be artificially provided.

Nigel Watson
Science writer
Nigel has written for several publications and websites, including *Aquila*, the *Fortean Times*, *Wired* and *History Today*.

THE MOON BY NUMBERS

400
The Sun is many times bigger than the Moon. It's about 400 times further from Earth, so they look the same size in the sky

29.5 DAYS
The length of a lunar month. It's longer than the amount of time it takes the Moon to orbit Earth

12
The number of people who have actually set foot on the Moon

3.8 CENTIMETRES
The distance the Moon is moving away from Earth each year

13 HOURS
The amount of time it takes to reach the Moon by rocket

16.6 KILOGRAMS
What you would weigh on the Moon if you weighed 100 kilograms on Earth

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SCAND

THAT SHOOK SPACE

SCANDALS OF EXPLORATION

Stealing, sabotage and safety concerns – from the silly to the serious, here are some of the wrongdoings that rocked the world of space

Written by Nikole Robinson

FABRICATED RESEARCH

Japan Aerospace Exploration Agency (JAXA) astronaut Satoshi Furukawa first flew into space as part of Expedition 28/29 in 2011, where he spent five months living in microgravity aboard the International Space Station (ISS). But his second visit to space was jeopardised due to controversy surrounding a research study overseen by the surgeon-turned-astronaut. Between 2016 and 2017, Furukawa was the supervisor of an experiment that simulated life on the ISS. Study subjects were confined in a closed environment for two weeks while researchers monitored their mental wellbeing and stress levels – an Earth analogue for conditions on the station. Two of the researchers involved in interviewing the participants edited and fabricated data that compromised the experiment and its results, revealed in 2019 after the study was investigated by an independent evaluator. "The creation of non-existent data undermines the credibility of the research content, and it was judged that it was an act that could be regarded as 'fabrication' from the perspective of researchers in general and society," JAXA officials wrote.

Though Furukawa didn't fabricate any results himself, his supervisory role and failure to disclose any wrongdoing makes him liable in the eyes of the Japanese space agency. Despite the scandal coming to light, Furukawa will not lose his place aboard the planned SpaceX Crew-7 mission, currently due to launch on 17 August 2023. Though still able to make his second trip into space, JAXA has stated that those involved will be appropriately punished.

"Furukawa will not lose his place aboard the planned SpaceX Crew-7 mission"

© NASA; Getty

SECRETLY MARRIED

The late 1970s saw a paradigm shift at NASA, who finally opened up astronaut applications outside of the military, looking for scientists and engineers who had the right stuff to fly aboard the upcoming Space Shuttle fleet. For the first time, women were encouraged to apply, with Sally Ride historically becoming the first female American astronaut in 1983. With crews now composed of men and women, NASA made it an unofficial rule that married couples couldn't fly together on the same mission to prevent any potential disruptions or favouritism – and to prevent the loss of both husband and wife if disaster were to strike.

Though they weren't the first astronauts to meet and fall in love, Mark C. Lee and Jan Davis were the first and only couple to circumvent this rule, flying together on the Space Shuttle Endeavour mission STS-47 as mission specialists. The two grew close after they were assigned to the mission in 1989, entering a relationship as they trained together before secretly tying the knot in January 1991. Given that their training was well underway and they were already familiar with the experiments that would be taking place on board, after a couple of months of deliberation, NASA officials decided to let them fly together. It remains the only exception to the rule, which is still in place today. Both astronauts flew two more missions for the Space Shuttle program, but not at the same time.

As well as carrying the couple, STS-47's Mae Jemison was the first African-American woman to go to space

A HOLE IN THE ISS

On 6 June 2018, a new team of astronauts headed to the ISS as part of Expedition 56/57. Commander Sergey Prokopyev travelled into orbit alongside American and German flight engineers Serena Auñón-Chancellor and Alexander Gerst on a Soyuz capsule, arriving without incident. Two months into their stay, ground control noticed changes in pressure brought on by a small breach. Instructed to locate the leak, the ISS crew soon discovered a round two-millimetre hole in the Soyuz orbital module. It was quickly repaired using epoxy sealant, and Roscosmos began to investigate what might have caused the hole to appear.

Micrometeoroids were ruled out, with the main theory becoming that the hole had been drilled. As the hole appeared to have been drilled from the inside of the module, some theorised that it could have been drilled during manufacturing or testing. Tensions ran high as Russia made allegations of sabotage by a member of the crew, attempting to place the blame on NASA's Auñón-Chancellor. NASA fought back against these baseless claims, providing data that no one had been near the Russian module near the time of the leak. Then head of Roscosmos Dmitry Rogozin claimed in 2019 that the agency had discovered exactly what happened, but would be keeping the information classified.

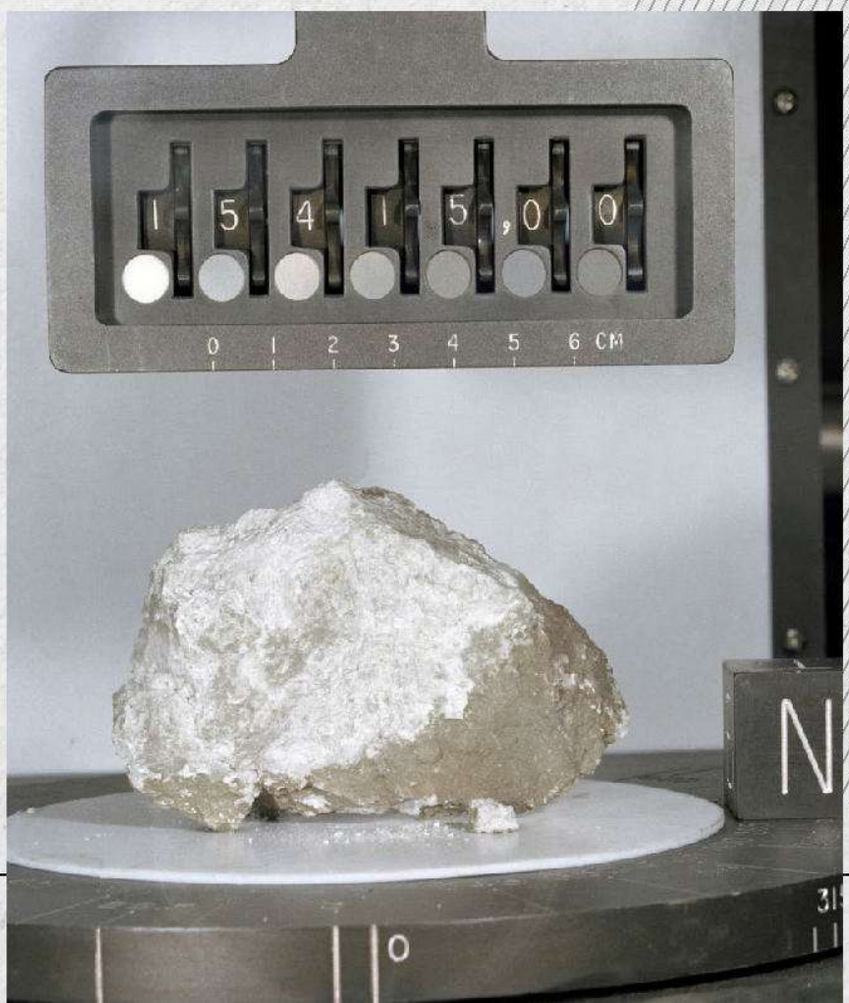
The hole looked like it had been made by a drill

STEALING THE MOON

Between 1969 and 1972, the Apollo missions delivered samples of lunar rock, soil and dust back to Earth for study, handpicked by astronauts from their various landing sites across the Moon's surface. Around 2,220 samples were returned, with a total weight of around 382 kilograms. Many remain in the Lunar Sample Building at NASA's Johnson Space Center. In 2001, NASA intern Thad Roberts realised some were stored under less-than-secure conditions, and began to hatch a heist.

In June 2002, his plan went into action. Roberts and his fellow interns Tiffany Fowler and Shae Saur snuck into Johnson facilities at night, using their keycards to access a room containing a safe full of lunar samples. The plan hit a small snag when they were unable to crack the safe, but the thieves remedied this by stealing the safe itself, which they later busted open with a power saw at a motel. The 101 grams of regolith inside were valued at around $21 million at the time. Under the pseudonym 'Orb Robinson', Roberts and student Gordon McWhorter arranged selling the rocks to a Belgian mineralogist named Axel Emmermann. Little did they know, he'd alerted the FBI to this suspicious sale. The Belgian worked with the bureau to set up a sting operation on 20 July – ironically the Apollo 11 anniversary date – and those behind the Moon rock robbery were arrested. Roberts, the ringleader, was charged with over eight years in prison, while his two female companions were given three years' probation and ordered to repay $9,000 in damages to NASA.

"Roberts and his fellow interns snuck into Johnson facilities at night"



Laika was a mongrel plucked from the streets of Moscow

Studying lunar samples has taught us much about our natural satellite

CANINE COVER UP

After the USSR surprised the world with the first satellite launch on 4 October 1957, the Soviets started to plan their next big endeavour – sending a dog into Earth orbit in order to monitor the effects of spaceflight on a living creature. This being the earliest days of space exploration, spacecraft didn't yet have the technology to de-orbit, so it was always understood that the Soviets were sending the dog to die in the name of science, raising ethical debates the world over.

Plucked from the streets of Moscow, Laika underwent brief but stressful training to get her used to the conditions of the Sputnik 2 satellite she would be launched aboard. The craft was fitted with devices to provide and regulate oxygen, as well as cooling fans, a food dispenser and a waste-collection system. A harness would restrict the dog's movement, with Laika only able to lie down, sit or stand in the same spot. Laika blasted off on 3 November 1957, closely monitored using the many sensors on board.

The Soviets popularised that the stray was euthanised before her oxygen supply ran out, using poisoned food to give her a painless death, though the story soon changed to announce she had run out of oxygen after six days of flight and passed away. Her real cause of death was hidden from the public until the turn of the 21st century. Laika only made it a few hours into her flight before dying from overheating, likely caused by the unsuccessful separation of payload and rocket.

© NASA ; Getty

CUT WIRES

STS-118 was a Space Shuttle mission carried out by Endeavour to deliver components to the ISS, scheduled to launch on 7 August 2007. While preparing and checking cargo due to be loaded into the Shuttle, it was discovered that the wires within a non-critical data relay box had been purposefully severed in an act of sabotage. The computer was due to be installed in the American-built Destiny laboratory module of the ISS. The space agency was alerted to the incident by a subcontractor around a month before the mission, and a formal investigation was launched. "It was disclosed to us as soon as the event occurred," William H. Gerstenmaier, NASA's associate administrator for human exploration and operations, said at the time. "The damage is very obvious, easy to detect. It's not a mystery to us."

The computer was sent to be repaired so that it could still be flown to and installed on the space station as part of STS-118, though due to its non-critical nature, the mission could have flown without it if necessary. The device's purpose was to collect structural performance data on the space station's main truss, which acts like the ISS' backbone.

Space Shuttle Endeavour preparing for the launch of STS-118

An example of one of the Apollo postal covers

POSTCARDS FROM APOLLO

David Scott, Alfred Worden and James Irwin were selected as the Apollo 15 crew. Coming back down to Earth on 7 August 1971, the mission was a success. But it would soon come to light that the crew had been involved in some less-than-stellar activities. The astronauts had agreed to ferry over 400 postal covers – stamped and addressed envelopes – to the Moon with them for a West German stamp dealer, Hermann Sieger The NASA crew were to be compensated $7,000 each in return, which they planned to save for their children. After Sieger put 100 of the covers up for sale in October 1971, the astronauts panicked – the original deal had assured them the covers would not be put up for sale until the end of the Apollo program. In 1972 NASA got wind of the unauthorised cargo, reprimanding the crew. Despite paying back their compensation, Deke Slayton removed the trio as the backup crew of Apollo 17. Though all three remained in roles at NASA, none of them ever flew in space again.

TOXIC SPACE JUNK

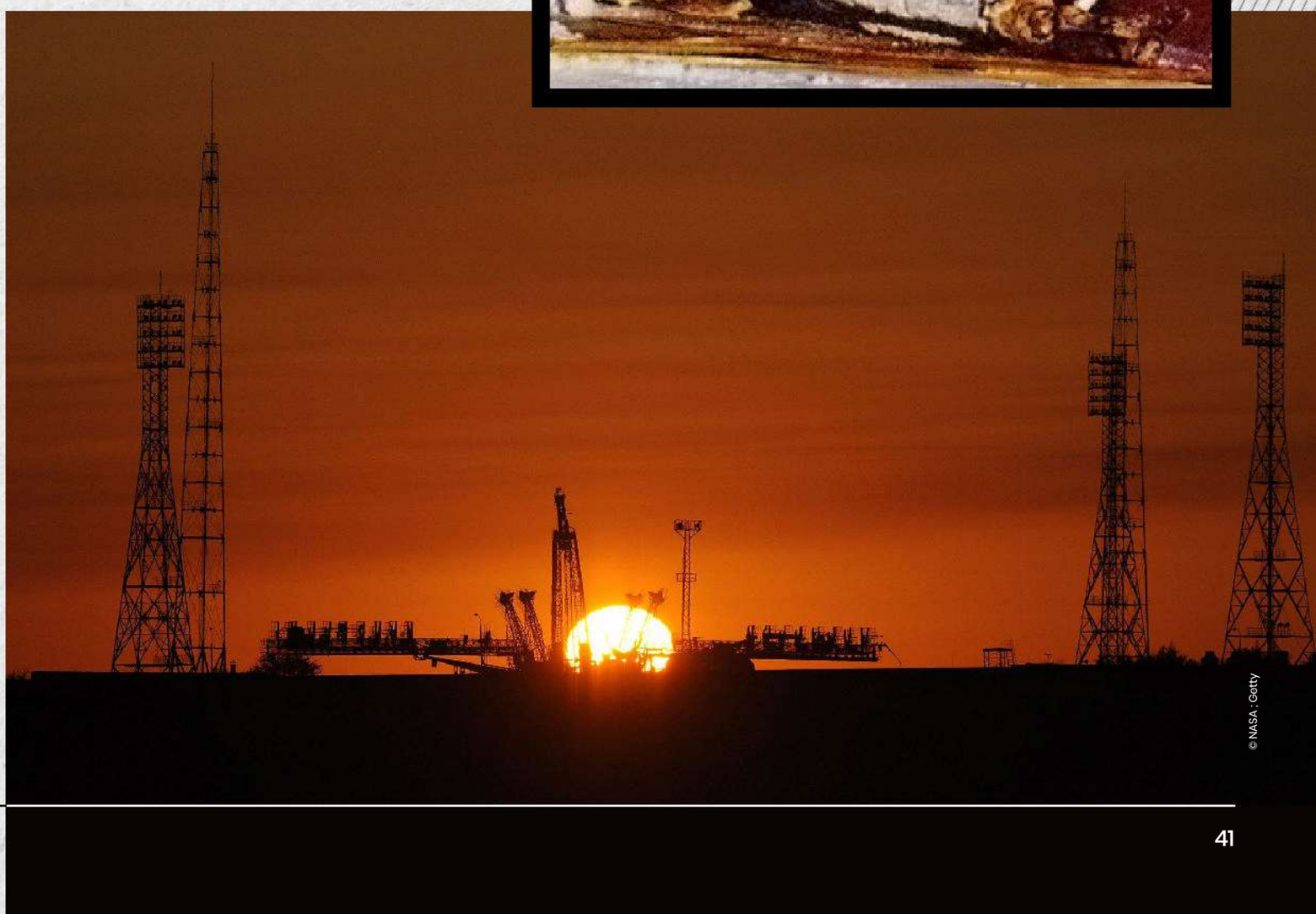
While the accumulation of space junk and defunct satellites in orbit is a whole other problem in itself, debris from rocket launches falling back to Earth may pollute the planet and cause environmental issues – especially those with radioactive or toxic fuel sources. NASA launches its rockets off the coast of Florida, meaning spent rocket stages and other debris fall into the Atlantic, away from populated areas. However, the former USSR and Russia's launch site is located in a landlocked area in Kazakhstan, in the desert steppe of Baikonur.

Built in 1955, the Baikonur Cosmodrome has been used since the historic launch of Sputnik in 1957, and was where Yuri Gagarin started his trip to the stars in 1961. 66 years of space exploration has meant a lot of debris dropping down to Earth. Due to the speed of the rockets, their spent stages can fall as far as 1,000 kilometres (620 miles) away in the Altai region of Siberia. An estimated 2,500 tonnes of space debris has rained down on the region since the launch of Sputnik, with some of the clutter as large as ten metres (32.8 feet) across. Residents within the flight path are warned 24 hours in advance of a rocket launch in order to prepare for the shaking ground and falling debris, but there have still been near misses with homes in the area. Residents fear that leftover fuel leaking from the fallen rocket parts is causing health problems, as well as seeping into water sources and soil, which may cause worsening problems down the line.

Spent rocket stages and other debris fall from the sky

Baikonur Cosmodrome is Russia's main launch site

"Built in 1955, the Baikonur Cosmodrome has been used since the historic launch of Sputnik in 1957, and was where Yuri Gagarin started his trip to the stars in 1961"



© NASA ; Getty

STS-81 was somewhat of a cultural exchange between the US and Russia

The 19th-century painting *Galileo Before the Holy Office* depicts the astronomer's trial

DRINKING PROBLEMS

With drinking even a small amount of alcohol and driving already considered a dangerous act on Earth, it makes sense that this rule would apply to spacecraft too. NASA banned the consumption of alcohol during spaceflights in 1972; the Russian space agency Roscosmos publicly shares this rule, but has been a little bit more lenient on allowing astronauts to drink in the past, with the cosmonauts who flew aboard the Mir space station allowed a small amount of cognac during their downtime. Famously, during the STS-81 visit to Mir, American and Soviet astronauts indulged in a drink of cognac together, sipping gravity-defying bubbles of booze. Despite an alcohol ban, there have been instances where beverages have been snuck aboard spacecraft. Cosmonauts have disguised alcohol as juice, hidden it inside hollowed-out books and even in a blood-pressure measuring device. Igor Volk and Vladimir Dzhanibekov went on crash diets a week before their flight on the Soyuz T-12 to the Salyut space station, losing weight so that they could smuggle the same volume of alcohol inside their spacesuits.

NASA had two instances reported in 2007 where "flight surgeons and astronauts identified episodes of heavy use of alcohol by astronauts in the immediate preflight period, which led to flight safety concerns." Though these astronauts were allowed to fly despite their preflight intoxication, a spaceflight safety review took place and astronauts were forbidden to consume any alcoholic beverages within 12 hours of a spaceflight.

"Famously, during the STS-81 visit to Mir, American and Soviet astronauts indulged in a drink of cognac together"

GALILEO'S PERSECUTION

For thousands of years, humans believed that Earth was at the centre of everything, with the Sun, Moon and stars all moving relative to our planet. This aligned with religious doctrine, placing god's most important creation at the centre of the universe. But as the equipment used to observe the heavens advanced, these views were brought into question. Nicolaus Copernicus first proposed that it was in fact the Sun that lay at the centre, with Earth and the other planets moving around it, in 1543. His revolutionary theory would be dubbed heliocentrism, and later observations by Johannes Kepler and Galileo Galilei would confirm his theory.

The Catholic Church saw this as an affront to god, banning writings on heliocentrism and declaring any opposition to an Earth-centric universe to be heresy. Galileo was investigated by the Roman Inquisition in 1616, and was warned away from supporting it. For over a decade he focused on other research, but in 1632 published his *Dialogue Concerning the Two Chief World Systems*, which had a strong bias towards heliocentrism. Once again Galileo was summoned by the Inquisition. Denying any wrongdoing, he claimed his book was intended to debate geocentrism and heliocentrism, and that his favouring of the latter wasn't intentional. Though this might have spared him from being executed, Galileo was placed under house arrest for the remainder of his life, even though we now know he was correct.

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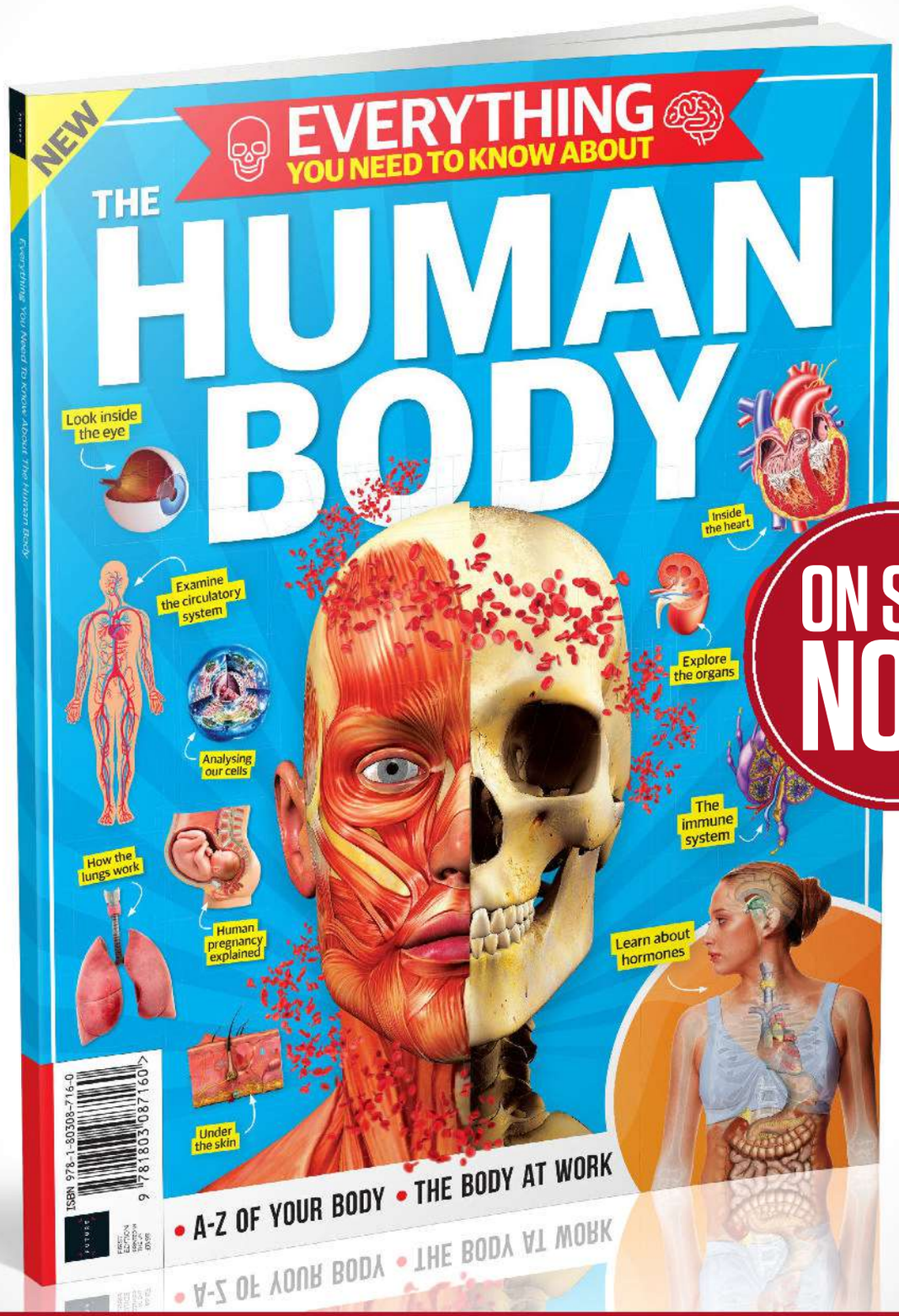

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INSTANT EXPERT

HOW ARE COMETS CLASSIFIED?

There are more than 5,000 known 'dirty snowballs' knocking about the Solar System, all of which fit into a selection of categories

Comets are known for their tails, and the name comes from the ancient Greek for 'long-haired'. The largest ones are a bright presence in the night sky for a month or so as they make their closest approach to the Sun. They are icy bodies – dirty snowballs of water ice mixed with rock, dust and frozen gases like carbon dioxide. The tail appears when the comet approaches the Sun and the surface layers turn to gas. This is then pushed away by the solar wind; it's mostly water and dust, though these can separate into two tails as the gas portion is more easily pushed outwards from the Sun than the dust.

Comets fall into three major categories: short period, long period and hyperbolic. While the vast majority do come from the Solar System, it's likely that some have come from outside of it, but there's no way to tell for sure. Short-period comets have orbits ranging up to 200 years and can be further divided into Encke-type, Halley-type and Jupiter-type.

Encke-type, named after Comet Encke, have orbital periods of less than 20 years, and their furthest distance from the Sun is still within the orbit of gas giant Jupiter. Jupiter-type comets have an orbit in the region of 20 years, and their furthest orbital point, or aphelia, is clustered around Jupiter's orbit. Halley-type are named after the iconic 76-year-period comet that was discovered by Astronomer Royal Edmond Halley in 1705. He used the work of his contemporary Isaac Newton to demonstrate that two historic comets were actually the same one returning every 76 years. Halley-type comets are generally believed to originate from the Kuiper Belt in the region of Neptune, and tend to be in regular elliptical orbits in the same general plane as the planets. They range in period

BIO
ROBIN HAGUE
Robin is a science writer, focusing on space and physics. He is the current head of launch at Skyrora, coordinating launch opportunities for Skyrora's vehicles and liaising with UK launch regulators.

Comet Lovejoy's blue-green glow comes from the organic molecules and water released by the comet

Halley's Comet

Comet Lovejoy (C/2014 Q2)

Comet Hartley

Comet ISON

Short period

These have periods from three years ranging up to 200 years and include the famous Halley's Comet, which returns every 76 years. They are generally in the same plane as the planets and are believed to have originated in the Kuiper Belt of objects near the orbit of Neptune.

Long period

Orbiting the Sun in cycles that take them anywhere up to thousands of years to complete, long-period comets are believed to originate in the Oort Cloud - a sphere of icy debris at the very edge of the Solar System.

Jupiter family

Regular comets that orbit in the general plane of the Solar System, those that belong to the Jupiter family have a period of around 20 years. They are classified together because their orbits are clustered around the gas giant's orbit.

Hyperbolic

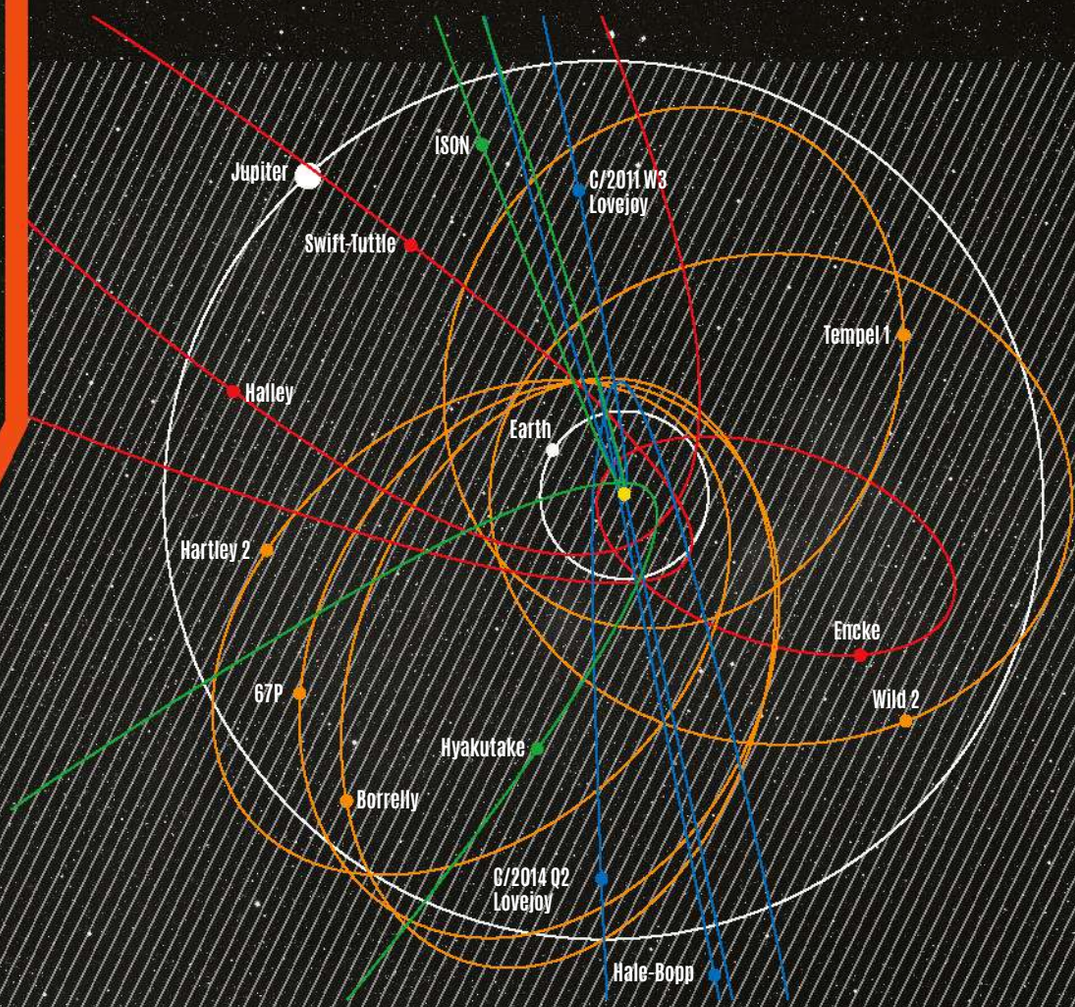
These have orbits that are open curves, carrying them out of the Solar System. They may have originated in the Oort Cloud, a huge sphere of icy debris surrounding the Solar System, or have entered from interstellar space.

from 20 years up to 200 years and cycle between the Kuiper Belt and the inner Solar System.

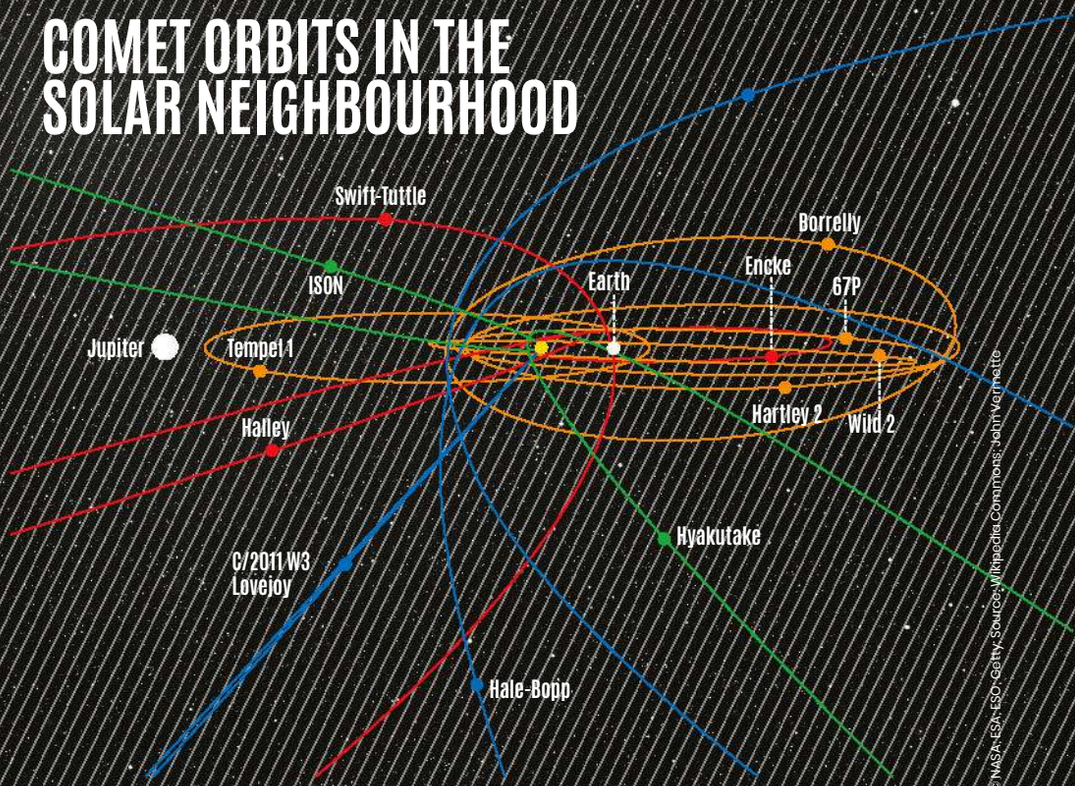
Long-period comets have periods greater than 200 years and cycle in highly eccentric orbits that can be at any inclination to the Sun's axis. They are theorised to come from the Oort Cloud, a vast sphere of icy debris expected to surround the Solar System from somewhere in the region of 2,000 to 5,000 astronomical units (AU) – one AU is the distance from Earth to the Sun – out to possibly as much as 100,000 AU, which is more than a light year.

Hyperbolic comets have an eccentricity greater than one, where a perfectly circular orbit has an eccentricity of zero and elliptical orbits have an eccentricity between zero and one. This means that they have an open path past the Sun and out of the Solar System; these comets may well include ones that have come from interstellar space, as such bodies are likely to be ubiquitous. We have even been able to detect the signatures of exocomets – comets orbiting other stars – by detecting how their tails block specific wavelengths of light when they pass in front of their parent star. Even light years away, comets are still famous for their tails.

"Halley-type comets are generally believed to originate from the Kuiper Belt"



COMET ORBITS IN THE SOLAR NEIGHBOURHOOD



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The Cassini spacecraft observed Saturn's equinox in 2009, but it won't be around for the next one in 2025

MYSTERIES OF THE UNIVERSE

WHAT CAUSES THE SPOKES IN SATURN'S RINGS?

Smudges around the gas giant have begun to appear again. Scientists have plenty of time to study them, but will they finally work out what's happening?

Reported by David Crookes

From a casual perspective, Saturn's iconic rings look almost perfect. Made up of billions of particles of ice and rock, which are thought to have come from comets, asteroids or shattered icy moons, they appear to seamlessly encircle the gas giant like a huge vinyl record. Since they were discovered by Galileo in 1610, the rings have become an immense source of fascination for astronomers, with so many discoveries having been made about them since. A lot of our knowledge of the rings came from the Voyager mission in the early 1980s, which gave us the first close-up images of the planet's complex system.

As Voyager 1 got within 50 million kilometres (30 million miles) of Saturn on 6 October 1980, it allowed astronomers to see some unusual marks. Rather than venturing in the same direction as the rings, they appeared to cut across them, like rods radiating from the centre of a wheel. Scientists had never seen this before, and they were intrigued to discover what may have been causing them. Named 'spokes' they've caught the imagination of researchers ever since. "The spokes are fascinating because they were so unexpected when Voyager flew by – we expected pristine icy and maybe rocky pieces, but didn't expect to see these ethereal dusty features," Dr Amy Simon, head of the Hubble Outer Planet Atmospheres Legacy (OPAL) program, tells **All About Space**. Yet there they were in all their glory, viewable again when Voyager 2 was within 4 million kilometres (2.5 million miles) of Saturn on 22 August 1981. And so a mystery was born.

© NASA/JPL-Caltech

A As Cassini looked at the sunlit side of Saturn's B ring from 11 degrees below the ring plane, it was able to take an image of the spokes in 2008

SATURN'S RINGS BY NUMBERS

282,000
KILOMETRES
The rings extend up to this far from Saturn

NINE
METRES
Each one is about 30 feet thick

7,000
The largest spans 7,000 times the planet's diameter

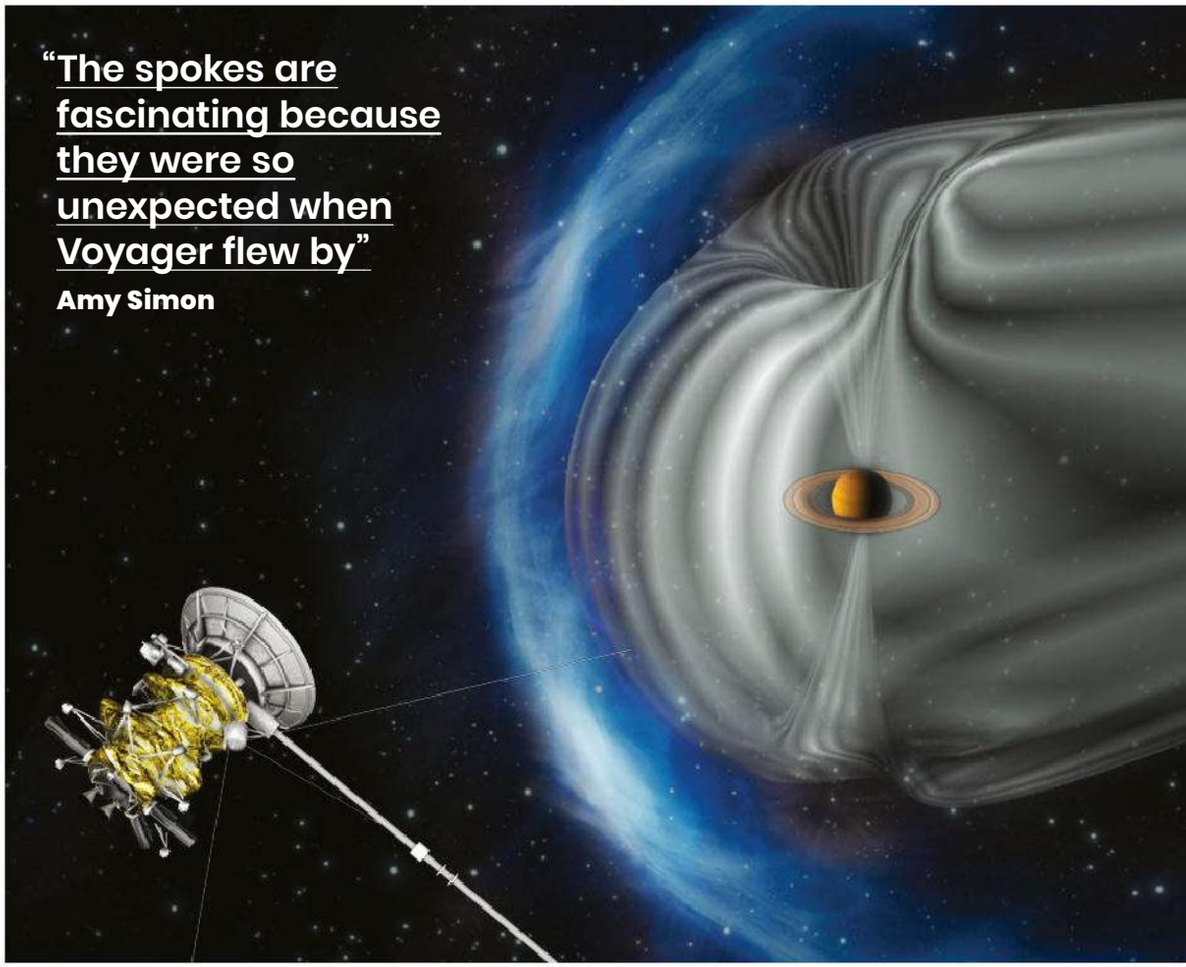
4,700
KILOMETRES
There's a thick gap between rings A and B called the Cassini division

2022
In this year, spokes appeared and disappeared for up to 11 hours

EIGHT
The duration over which they appear in years

14.5
They peak during Saturn's equinoxes, every 14.5 years

6 MAY 2025
The next equinox



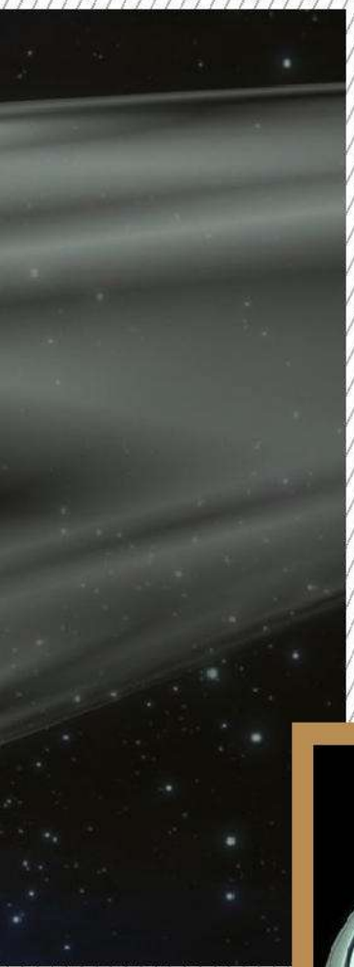
"The spokes are fascinating because they were so unexpected when Voyager flew by"
Amy Simon

The spokes orbit in the planet's B ring, and it soon became clear that their presence wasn't consistent with gravitational orbital mechanics. Rather it suggested that other forces were able to affect the rings, and scientists began to piece together some clues. "The spokes are levitated dust clumps," Simon says, by way of a start. "The rings themselves are governed by the gravitational field of the planet, plus small moons that shepherd the rings and can cause other short-lived structures." Depending on the viewing and illumination angles, the spokes can look dark or light. They also appear to be transient features, meaning they come and go over a short period of time. "The spokes are fuzzy patches that rotate along with the rings and last a few hours at most," Simon explains. "They are usually dark patches against the bright rings, but if viewed from the dark side of the rings they can appear bright."

For a few years scientists could only work with Voyager's images to come up with theories as to what was causing the spokes. But then the Hubble Space Telescope, which launched into low-Earth orbit in 1990, was able to peer at the planet, leading to more revelations. "The spokes were actually observed by Hubble in the 1990s, disappearing in 1998," says Simon. "It led to the first indication that the spokes might be somewhat seasonal." To explain, since Saturn is tilted on its axis, the planet has four seasons, just like on Earth. It takes around 29 Earth years to orbit the Sun, so each of those seasons last for seven Earth years. The spokes appear at a particular point – specifically during Saturn's equinoxes, when the planet's rings are tilted edge-on towards the Sun. This occurs every 14.5 Earth years in Saturnian spring and autumn, with the next one due to take place on 6 May 2025.

Understanding that the spokes appear seasonally was a major breakthrough. It has enabled scientists to better target their observations of the planet and discover more about the timings of them – there has been no point trying to observe them during Saturn's solstices in summer or winter, for instance, because the spokes are not visible when the Sun reaches its highest or lowest latitude in the planet's northern or southern hemisphere. "We first suspected that the spokes were seasonal in the late 1990s thanks to the Hubble observations that occurred after Voyager," says Simon. "Based on that, it was predicted that the spokes would be visible to Cassini in 2005 or 2006. With the few examples that we have, the spokes have begun to appear roughly on schedule, though the end of the spoke season is less precise."

The last time Saturn's equinox was observed was in 2009 when NASA's Cassini's spacecraft captured the narrow spokes using its wide-angle camera, showing



Saturn is surrounded by a giant magnetic field, but how it's generated is a puzzle

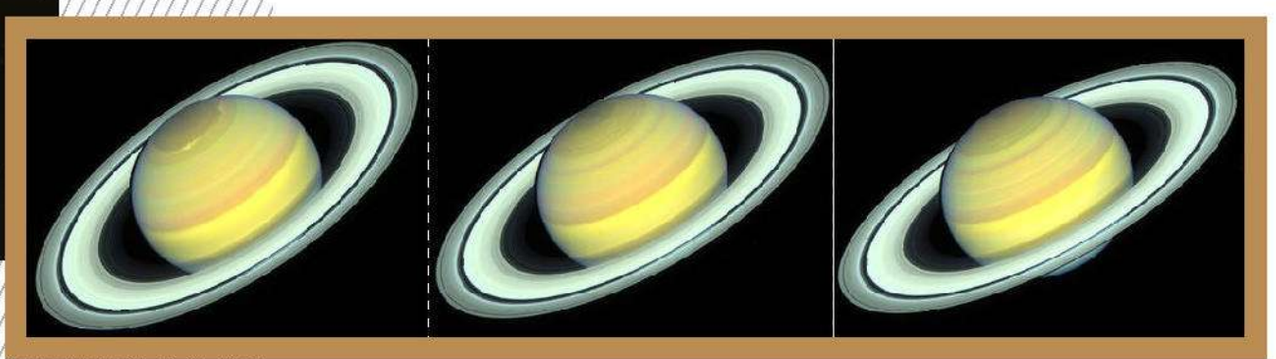
Hubble's observations of Saturn are showing changes in the planet's atmosphere as summer turns to autumn

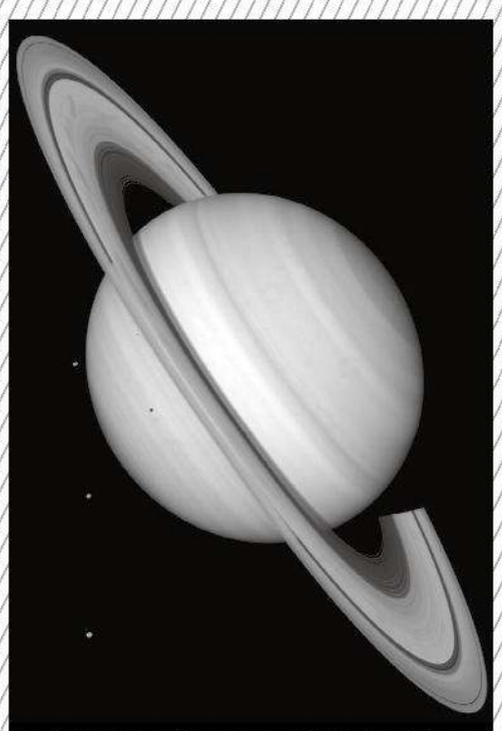
In this stunning view of Saturn by Voyager 2, you can see the ring spokes which Hubble and then Cassini later observed

them to be as long as 3,500 kilometres (2,200 miles) and about 100 kilometres (60 miles) wide – although some of them look more like blobs than classic radial spoke shapes. As the planet moved towards its summer in 2013, the ghostly streaks began to disappear again. But spoke season is upon us once more, and scientists are already observing them, waiting to see what secrets they may be hiding.

Saturn's spokes are expected to become increasingly prominent and observable over the coming months, and Hubble is set to capture them in all their glory as part of the OPAL program. The predictions were that they would appear around the beginning of the current decade, and they did just that in 2021. It has already allowed for some observations from September 2022, when the spokes were spotted over an 11-hour timeframe. But even though scientists are able to make such estimates about their appearance, they're still in the dark in terms of knowing just why they appear at this time. "Right now we're uncertain about the exact mechanism forming the spokes and what triggers their first appearance," Simon says. "The spokes can also be very faint and sporadic when they first appear. Without constant monitoring, it's difficult to pinpoint exactly when they first appear."

How long they'll stick around is also difficult to figure out, but that's going to be one of the things scientists hope to be able to better pin down. "The duration is much harder to predict," Simon continues. "But that could indicate that whatever is charging the particles doesn't dissipate as soon as the Sun angle becomes less favourable." One thing's for sure, scientists are going to monitor Saturn and observe any changes for a good few years in order to build a solid archive of data.





THREE POTENTIAL EXPLANATIONS

A few theories have sought to explain the spokes in Saturn's rings

They're made by meteoroids

Shortly after Voyager's discovery, scientists began to think that meteoroids striking the rings at high velocity were producing clouds of dense plasma. This in turn was causing the dust grains in the rings to become charged, forcing them to levitate above the ring plane. They would then drift relative to the plasma. But why would this only happen seasonally?

They're spawned by storms

In 2006 scientists put forward the theory that the spokes are being created by massive thunderstorms in Saturn's atmosphere. It was proposed that energetic beams of electrons produced above the storm surge upwards and electrically charge dust particles in the rings. The dust is then lifted, creating the spokes.

They're created by Saturn's magnetic field

An interaction between Saturn's magnetic field and the solar wind is most likely to be the cause of the spokes. This theory suggests that charged dust particles suspended above and below the rings interact with the planet's magnetic field, and this causes the spokes to rotate with Saturn's interior spin.

© NASA; ESA; STScI; A. Simon; R. Roth

"We first suspected that the spokes were seasonal in the late 1990s thanks to the Hubble observations that occurred after Voyager"

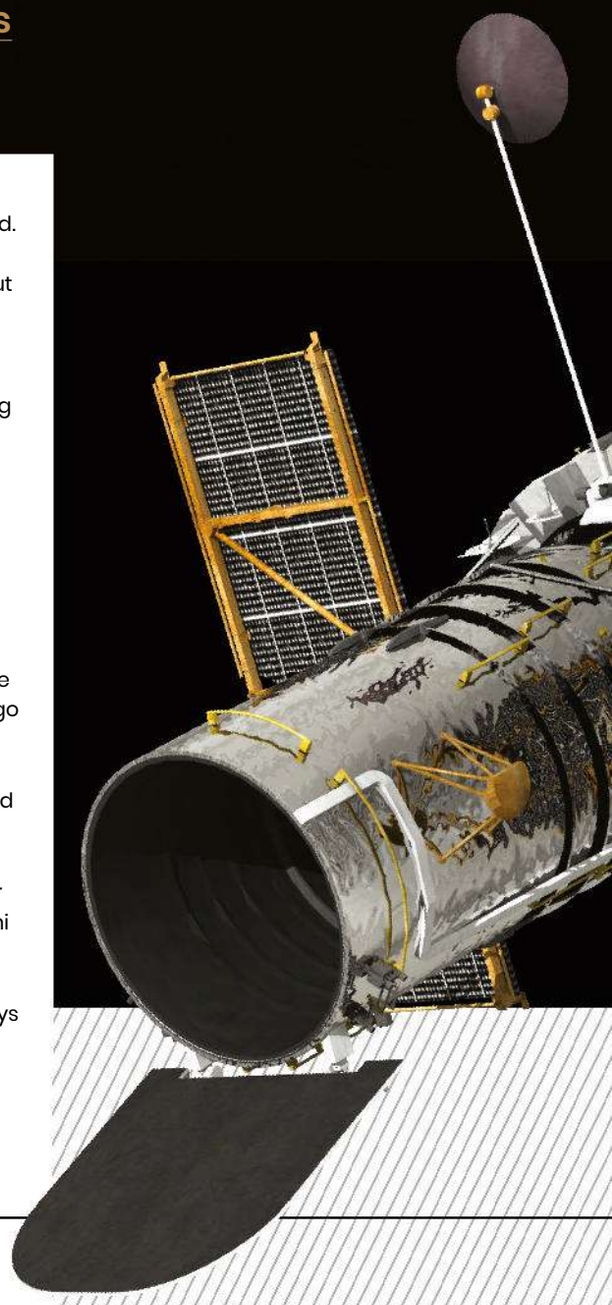
Amy Simon

In doing so, scientists will spend longer studying the spokes than at any time in history, and it could go a long way towards determining their cause. Likewise, they will be able to better ascertain just why the spokes appear when the planet is undergoing an equinox. "We don't yet know what is special about this time period," says Simon. "It was originally thought to be an observational effect – that the proper angle was needed to see the spokes – but after Cassini observed from many angles, we know that's not true. However, there could be a specific alignment of Saturn's magnetic field with the solar wind that occurs as equinox approaches."

One theory being tested is whether or not Saturn's variable magnetic field is playing a key role in the creation of the spokes. It's believed that tiny, icy ring particles are becoming charged when Saturn's magnetic field interacts with the solar wind, causing them to levitate – albeit temporarily – above the other icy particles and boulders. Using Hubble's visual and spectroscopic data, in wavelengths of light from ultraviolet to near-infrared, could provide answers. "There are several possible processes, but all involve the magnetic field either charging and lifting particles from static discharges, or interacting with charged solar wind particles," says Simon. "What we don't yet know is the exact mechanism causing the charging and lifting and why certain magnetic longitudes appear to be preferred. There's still work being done to analyse the extensive Cassini datasets to better suss out the interactions."

As always, more is more. The greater the amount of data scientists can amass, the better the chance they have of cracking celestial conundrums like this. "Although Cassini ended several years ago, we have so much more data to analyse – there will be more results to come from both that data and from Hubble," Simon explains. It's work such as this which has led to astronomers working out that Saturn's rings are less than 100 million years old, for example, rather than being born at the time of the planet's formation 4.5 billion years ago or in more recent times. It also shows the ongoing importance of Hubble, which has been in operation for over 33 years now and is predicted to continue until the 2040s, maybe even beyond.

Hubble is certainly going to be crucial for understanding the spokes. "Although Cassini had far more frequent time coverage of the rings, we could only observe a single spoke season due to Saturn's long year," says Simon. "More data is needed over several spoke seasons to better understand the correlation between spoke appearance and the ring-Sun magnetic field geometry." And yet there's also a chance that work



SPOTTING THE SPOKES

Just what are the scientists of the Outer Planet Atmospheres Legacy program looking for?

1 B ring

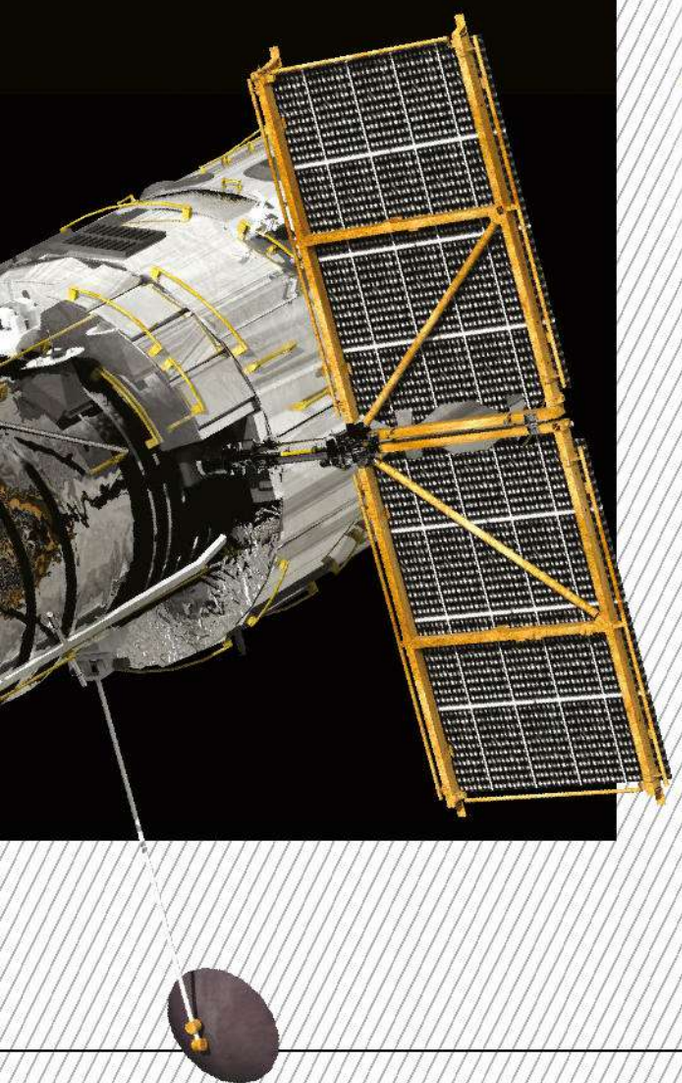
Of the seven rings of Saturn, the B ring is the largest, brightest and most massive. Made of chunks of water ice, you can see this ring when you look at the planet through a telescope.

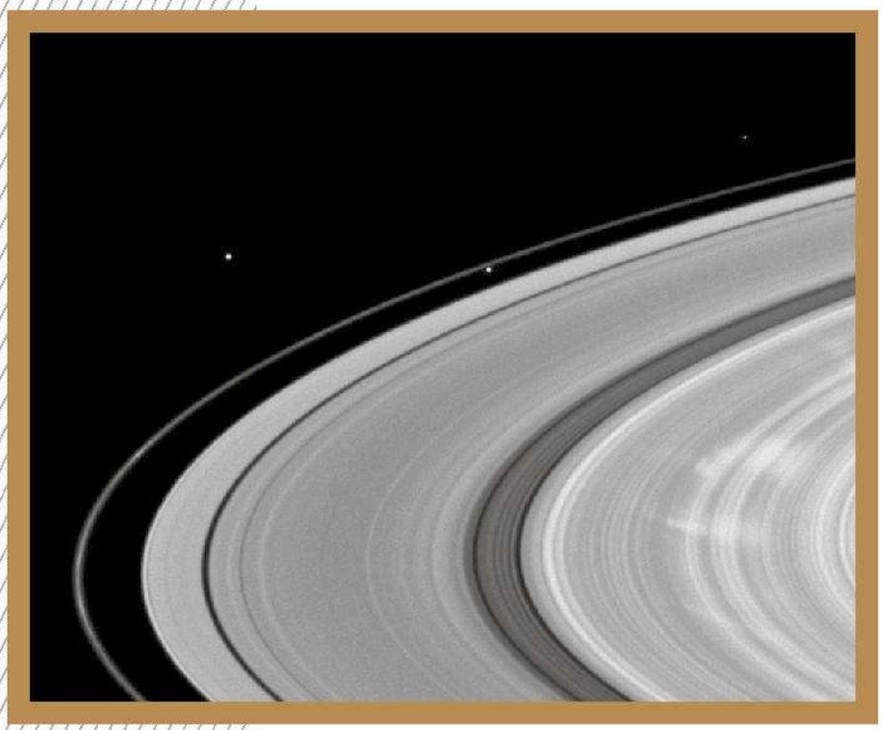
2 The gas giant

Saturn is tilted on its axis, and it spins very fast. A Saturn day lasts 10 hours and 14 minutes, but it slowly makes its way around the Sun, making an orbit every 29 Earth years.

3 Spokes spring in

The spokes will appear in various shapes and shades over the next few years. They can sometimes look like blobs or, as befitting their name, like the spokes on a bicycle.





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Taken just before Saturn's equinox in August 2009, this image shows the spokes shining brightly

The Hubble Space Telescope is already observing Saturn's rings and pulling in data about the spokes

on Saturn can extend to other planets where a similar phenomenon could be taking place – although, it must be pointed out, such spokes have not been found elsewhere in the Solar System yet. After all, Saturn is not the only gas giant to have rings: Jupiter, Uranus and Neptune do too. Saturn's rings are much more prominent, forming the most extensive ring system of any planet in our Solar System.

By combining Hubble and Cassini data, more than one mystery could end up being resolved in the future. It could also tell astronomers more about ring physics in general. "The other planets have much more sparse rings, so while they could have similar interactions, they would be very difficult to see," says Simon. "Uranus and Neptune also have very complicated magnetic fields, which could cause interesting effects in the rings. We look forward to exploring this in detail some day!"

For now, though, all eyes are going to be on Saturn's rings as scientists watch out for the spokes and begin to study them in more detail. If a breakthrough is indeed made, it would represent another triumph for the OPAL team. In obtaining long-time baseline observations of the gas giants, they've been trying to understand their atmospheric dynamics and evolution. This Hubble program has already discovered a new Great Dark Spot on Neptune and uncovered more details about a complex storm system in Saturn's north polar atmosphere. Getting to the bottom of another Saturn mystery is sure to have them dancing like the dark spokes on that Saturn vinyl.

David Crookes
Science and technology journalist
David has been reporting on space, science and technology for many years, has contributed to many books and is a producer for BBC Radio 5 Live.

SEARCH FOR LIFE

Why do we send messages into space to search for alien life?

I think we just have to do whatever experiments are available to us. I don't think anybody would pretend that sending messages was the most efficient way of finding extraterrestrial life, but that's all that's been available, isn't it? It's extraordinary that, here on Earth, radio waves are quite an old technology and not a technology that we're expected to use much longer for interstellar communications. Lasers are taking over, and who knows, gravitational waves may take over after that. So it's kind of about what's available to us, and the belief that we can look and should look. Even with the most optimistic estimates for the number of intelligent civilisations out there, we are still going to have to search a million or 10 million Sun-like Solar Systems before we find a civilisation that we can signal to. There will be others out there, but the timing won't be right.

Ben Miller presented an episode of the BBC science series *Horizon* and wrote *It's Not Rocket Science*

Did you know?

The Arecibo message was sent in the direction of Messier 13

- If life does exist elsewhere, it might not use radio waves to communicate
- Will there be wars for Mars?
- Solar sails use photons for propulsion

SPACE EXPLORATION

Do land laws apply to the Moon and Mars?

International space law also applies to celestial bodies within our Solar System, like the Moon and Mars, despite what some corporations might assert. There are important principles that apply to activities on celestial bodies, but we clearly will need to think carefully about augmenting these to provide clarity for future activities. Take potential human settlements – we will need to work out how the people interact and what laws will govern them. Eventually, it may be that they may want to marry or have children. What nationality will they have and what will be the guiding principles of behaviour in such unique environments? These are questions for another day, but those discussions are beginning even now.

More immediately, there's now great excitement about the possible exploitation of space resources on celestial bodies. This is a big issue that, in some senses, will define our future relationship with space. There are many conversations on this issue taking place at all levels, and the Australian government at the United Nations Committee on the Peaceful Uses of Outer Space (COPUOS) has been actively engaged and has recently established a working group on the issue.

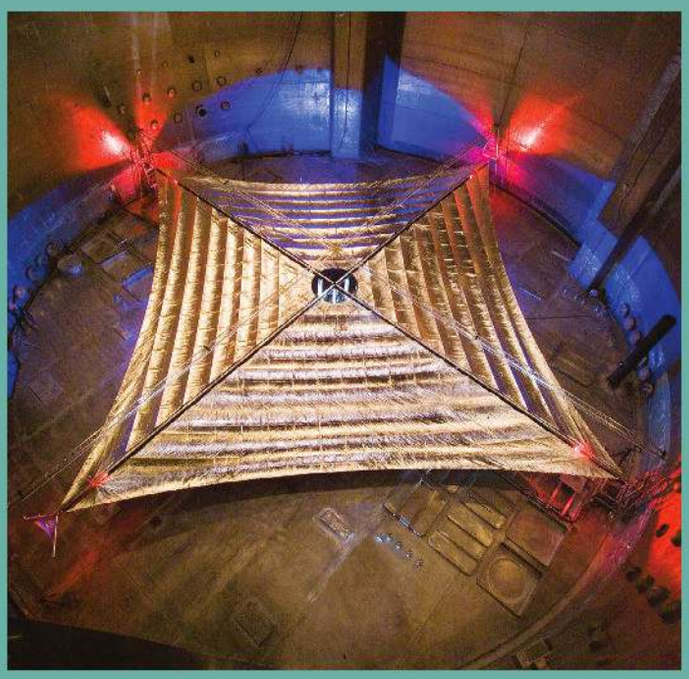
Steven Freeland, Emeritus professor at Western Sydney University and Professorial fellow at Bond University

SPACE EXPLORATION

What impact will solar sails have on the future of space travel?

We're designing missions that use solar sails to be very future-proof. We're designing them to go out and demonstrate all of the capabilities and all of the things necessary to scale them to much larger areas – up to 65,000 square metres (700,000 square feet). We're thinking about how we can create very large sails to do much more intensive missions. Secondly, when we talk about solar sails being propellantless, I like to think that the future isn't solar sail proof. We're designing a new way to propel spacecraft that's going to cause spacecraft designers to have to think a little differently. Right now a lot of spacecraft are built around how much fuel they can carry, so the battery only needs to be good for 15 years because there's only 15 years of fuel on there. Now that we've lifted the burden of time from the designers' plate, they need to begin to think about spacecraft that have lifetimes on the order of the Voyager spacecraft. I think we're going to force some technology jumps in components and in spacecraft building that may not have otherwise occurred.

Nathan Barnes, president of the L'Garde aerospace company. He is responsible for all operations at the company and is the principal investigator for the L'Garde NASA Technology Demonstration Missions solar sail program



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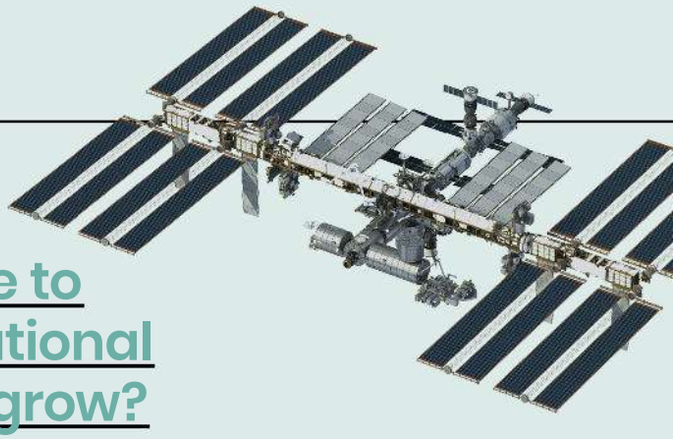
SOLAR SYSTEM

Why did it take so long to find the source of Enceladus' geysers?

Other than to look for plumes coming off Enceladus, which we first saw in February 2005, we had no other plans for specific observations of geysering activity. Once we found them, we altered the nominal mission as much as we could to get a closer look. This included a set of Cassini flybys to measure the mass distribution within the outer layers of the moon in the south-polar region, as well as very high-resolution images of the geyser field and Enceladus' surface. It wasn't until 2013 that we had confirmation of a liquid layer about ten kilometres (6.21 miles) thick under the south-polar terrain. We realised that it was at least as wide as the south pole region, but a global ocean couldn't be ruled out. Under certain reasonable assumptions, some analyses suggested it should be global. But that conclusion didn't carry a high degree of confidence.

It wasn't until recently that my team members finally finished their work utilising our high-resolution images of the surface. We managed to tease out a small wobble in the rotation of Enceladus that is best explained by a global ocean. These analyses are all – at this stage in the research – very sophisticated, requiring more than just a look-see engagement with an image, but a lot of work. And good, careful work takes time.

Carolyn Porco led the imaging science team on the Cassini mission to Saturn



SPACE EXPLORATION

What was it like to see the International Space Station grow?

There were a lot of unknowns. Talking about the STS-88 mission, Nancy Currie-Gregg grabbing the node and putting it on the end of the docking system and then going up and grabbing the Russian Zarya and putting them together, that was a hard thing to do; it was the longest stretch of the Shuttle robotic arm we'd ever done and it didn't quite latch the first time. We had to do it again, and then the crew entered it and it was this really neat, clean space, and just from there the complexity ramped up exponentially, just putting different pieces onto it and then building out the truss and having it survive over time. I think the really tough part for me of learning how to build this enormous structure in space was that it had to be a viable spacecraft the whole time. We had people living in it and we had to provide a safe environment and provide power and cooling and all the logistics you need to live while you're building it. It wasn't like a ship you can just build in dry dock and launch when it's all finished up. We had to really think through how all the systems would work as we were building it out in the most hazardous environment that people can operate it.

John Shannon led the International Space Station (ISS) program for Boeing in its key integration role for NASA

GALAXIES

Is there much between the voids of galaxies?

If you had some sort of ramjet technology where you're trying to scoop up material to fuel your ship, you're certainly going to have a harder time of it in the voids. The density of matter in our Solar System is already high compared to the rest of the Milky Way. One proton per cubic centimetre is typical for our galaxy as a whole, which is many times – maybe 1,000 – higher than the space in the void, and in the Solar System, it's many times higher than in our galaxy.

An important point is that these larger structures have been at the centre of the realisation that most of the gravity is coming from dark matter rather than light matter. And they're quite important for understanding the history of the universe because the size of these structures tell us what has happened over the history of the universe.

Peter Eisenhardt, former project scientist for NASA's Wide-field Infrared Survey Explorer (WISE) mission, now known as NEOWISE

- The first ISS module launched in 1998
- The space between galaxies is much less dense
- String theory could unite gravity and the quantum world

COSMOLOGY

Why is string theory considered to be the theory of everything?

String theory is a single equation that allows us to summarise all the laws of the universe. Einstein spent 30 years of his life chasing after the theory of everything. He wanted an equation that would allow us to 'read the mind of god'. We have two great theories of the universe. We have quantum theory, the theories that are very small that give us lasers and atomic bombs and iPods and iPads and the Internet. That's quantum theory, the theory of the very small. Then we have the theory of the very big – Einstein's theory of gravity and black holes and Big Bangs – but these two theories hate each other. These two theories don't like each other, so why would nature create a left hand and a right hand that don't talk to each other? That's crazy!

We think that there's one theory that unifies quantum theory with relativity, and that is string theory. Why do we have so many particles? We have electrons, neutrons and neutrinos. We spend billions building atom smashers to find more and more particles. There are 36 quarks and 19 free parameters in the Standard Model, and we think that all these subatomic particles are nothing but musical notes on a tiny vibrating string. And what is physics? Physics is harmonies, the laws of harmonies of tiny vibrating strings, that's physics. What is chemistry? Chemistry is nothing but the melodies, the melodies you can play when these strings bump into each other, creating molecules. What is the universe? The universe is a symphony, a symphony of strings. The 'mind of god' is cosmic music resonating through 11-dimensional hyperspace.

What is matter? Why do we have planets and stars and galaxies? Why is there life? It's nothing but music. Music is the only paradigm rich enough to explain electrons, neutrinos, protons, DNA, stars and galaxies. It's the only paradigm rich enough to explain the universe, and that's what string theory is. String theory is considered to be the theory of everything, explaining that we are nothing but musical notes and melodies played beautifully on vibrating strings.

Michio Kaku, professor of theoretical physics at the City College of New York

© Getty Images; Shutterstock; 3Dsculptor

SUMMER STARGAZING

The warmer months have many a space spectacle to offer, and the weather makes for more comfortable viewing

Reported by by Colin Stuart

Summer can be a blessing for stargazers, and it tends to bring out casual night-sky watchers, too. There are certainly many spectacles to glimpse, from planets and stars to globular clusters and distant nebulae.

It's the globular clusters that can hold particular majesty this time of year. Huge conglomerations of ancient stars, they often contain hundreds of thousands of members, all packed into a relatively small part of space. If you were to find yourself on a planet orbiting one of those stars, you would see tens of thousands of stars in your night sky. The output of the starlight from this host would easily be enough for you to read a book in the pitch black of the middle of the night. A sky like this would put the best stargazing spots in the world to shame.

The Milky Way also shows us its more spectacular side in the summer as the galactic centre briefly peers above the horizon, allowing us a glimpse into its spectacular dust lanes. The zodiac constellation of Sagittarius, with its famous Teapot asterism, is the place to look.

As with all times of the year, you'll need a range of observing equipment depending on what you're trying

JARGON BUSTER

Globular cluster
A collection of ancient stars densely packed together in a roughly spherical group that's bound together by gravity.

Asterism
A familiar pattern of stars, but not an official constellation – the most famous example being the Big Dipper, or Plough.

KEY

Naked eye

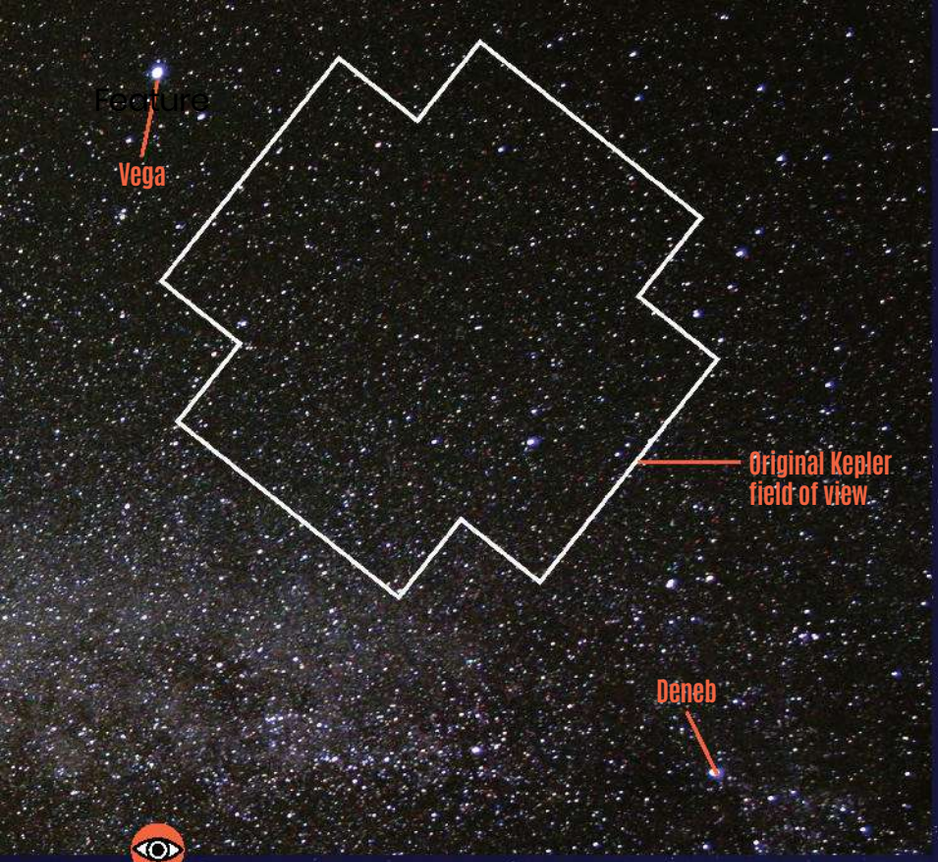
Binocular

Small telescope

to look at. For some objects simply your eyes will suffice, but for others you'll need a binocular or even a small telescope. For fainter objects, it's worth remembering that a bright Moon will compete for your attention, so try to avoid it.

The Sun will interfere with astronomy too. It may seem counter-intuitive to talk about the Sun affecting night-time observations, but in the summer it never dips far below the horizon. It's therefore able to return to the sky quickly, leading us to shorter nights and less opportunity to gaze at cosmic wonders. Even from its position beneath the horizon it's still capable of beaming some of its light into the lower parts of the sky, meaning faint objects close to the horizon present more of a challenge than they would in the winter – nature's own summer light pollution.

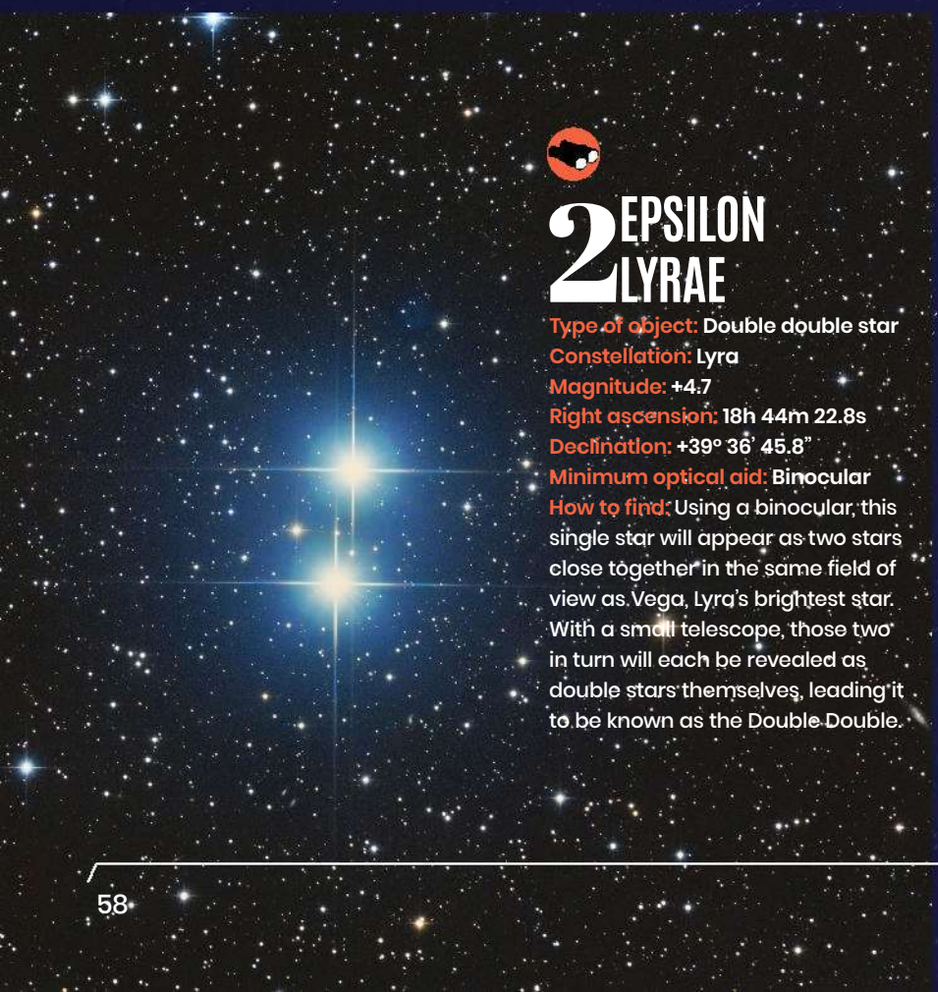
Don't let that put you off, though. Jewels like the scintillating double star Albireo in the constellation of Cygnus and mesmerising open clusters such as the Coathanger and the Wild Duck will more than make up for the shorter nights, keeping you occupied until Orion and company return to the skies this winter.



1 ORIGINAL KEPLER FIELD OF VIEW

Type of object: Exoplanet region
Constellation: Cygnus and Lyra
Magnitude: N/A
Right ascension: N/A
Declination: N/A
Minimum optical aid: Unaided eye

How to find: If you look directly between the bright stars Deneb in Cygnus and Vega in Lyra, you'll be peering into the same region as the Kepler Space Telescope when it was first launched. This region is home to some of the Earth-like planets it has revealed beyond our Solar System. Perhaps someone is looking back at you.



2 EPSILON LYRAE

Type of object: Double double star
Constellation: Lyra
Magnitude: +4.7
Right ascension: 18h 44m 22.8s
Declination: +39° 36' 45.8"
Minimum optical aid: Binocular
How to find: Using a binocular, this single star will appear as two stars close together in the same field of view as Vega, Lyra's brightest star. With a small telescope, those two in turn will each be revealed as double stars themselves, leading it to be known as the Double Double.

3 ALBIREO

Type of object: Double star
Constellation: Cygnus
Magnitude: +3.55
Right ascension: 19h 30m 43.3s
Declination: +27° 57' 34.8"
Minimum optical aid: Binocular
How to find: Albireo sits at the 'beak' of Cygnus (the Swan). Find the bright star Deneb, follow the line through its wings and continue along its neck until you reach the double star, with its components shining golden yellow and electric blue. One of the widest doubles in the sky, it doesn't take much optical power to prise them apart.

4 BROCCHI'S CLUSTER

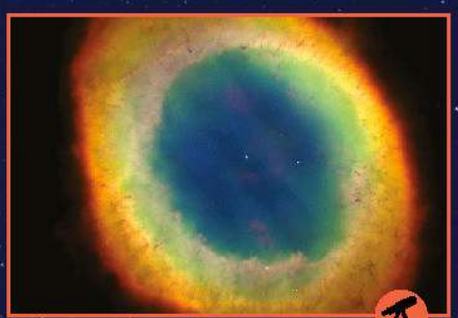
Type of object: Open cluster
Constellation: Vulpecula
Magnitude: +3.6
Right ascension: 19h 25m 24s
Declination: +20° 11' 00"
Minimum optical aid: Binocular
How to find: Known as the Coathanger due to the shape traced out by its stars, Brocchi's Cluster is one of the easiest open clusters to observe in the sky. Place your binocular on Albireo, follow a straight line through Alpha Vulpeculae and continue in that direction until you find the cluster.

5 MESSIER 13

Type of object: Globular cluster
Constellation: Hercules
Magnitude: +5.8
Right ascension: 16h 41m 41.2s
Declination: +36° 27' 35.5"
Minimum optical aid: Binocular
How to find: Called the Great Globular Cluster in Hercules, this beautiful grouping of ancient stars is found on the right-hand side of the Keystone – the asterism of four stars that makes up the body of Hercules. It's located about a third of the way down between the stars Eta and Zeta Herculis.

6 SUALOCIN AND ROTANEV

Type of object: Stars
Constellation: Delphinus
Magnitude: +3.8 and +3.6
Right ascension: 20h 39m 38.3s and 20h 37m 33s
Declination: +14° 35' 42.3" and +15° 54' 43.4"
Minimum optical aid: Unaided eye
How to find: These two stars form the right-hand side of a four-star asterism known as Job's Coffin. They're noteworthy because when spelt backwards they become the Latin name of a Sicilian astronomer, who managed to sneak his name into the history books and the heavens.

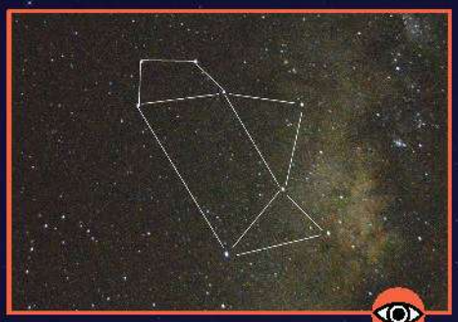


7 RING NEBULA

Type of object: Planetary nebula
Constellation: Lyra
Magnitude: +8.8
Right ascension: 18h 53m 35.1s
Declination: +33° 01' 45"
Minimum optical aid: Small telescope
How to find: Beneath the bright star Vega sit four dimmer stars arranged in a quadrilateral. The Ring Nebula – the leftover remnant from the death of a star like the Sun – sits about halfway along the short, lower edge and looks a lot like someone has blown a smoke ring in the sky.

8 DUMBBELL NEBULA

Type of object: Planetary nebula
Constellation: Vulpecula
Magnitude: +7.4
Right ascension: 19h 59m 36.3s
Declination: +22° 43' 16.1"
Minimum optical aid: Binocular
How to find: One of the first planetary nebulae to be discovered, find it by starting with Albireo in Cygnus. Pick out the line between Vulpecula's bright Alpha Vulpeculae and 15 Vulpeculae. Bisect this line and continue onwards for about the same distance and you'll find Messier 27, the Dumbbell Nebula.



9 THE TEAPOT

Type of object: Asterism
Constellation: Sagittarius
Magnitude: +1 to +3
Right ascension: 18h 27m
Declination: Centred around −30°
Minimum optical aid: Unaided eye
How to find: One of the most famous asterisms in the sky, the Teapot forms a large part of Sagittarius's torso, head and bow arm. Locating it is an easy way to make sure you are looking approximately towards the centre of our Milky Way galaxy, where the density of stars and dust lanes increases dramatically.

10 THE MOON

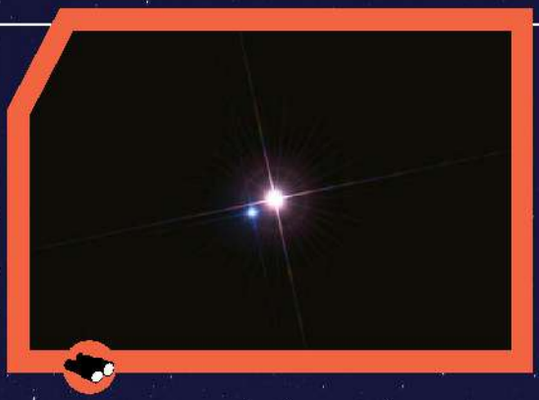
Type of object: Natural satellite
Constellation: Sagittarius & Pisces
Magnitude: −12.8
Minimum optical aid: Unaided eye
How to find: 3 July, 1 August, 28 August and 29 September see an unmissable range of full 'supermoons', when the Moon's greatest phase coincides with its closest position to Earth. It should appear slightly bigger in the sky at this point. Although without the shadows provided by lesser phases, it will be harder to pick out details in craters and mountains.

11 NGC 869 AND NGC 884 (THE DOUBLE CLUSTER)

Type of object: Open clusters
Constellation: Perseus
Magnitude: +3.7 and +3.8
Right ascension: 2h 20m
Declination: +57° 08'
Minimum optical aid: Unaided eye
How to find: Locate the distinctive 'W' shape of Cassiopeia. Of the five brightest stars, take the most central one, then head left and down towards Ruchbah. Keep going along this line and you can't miss these young groups of stars.

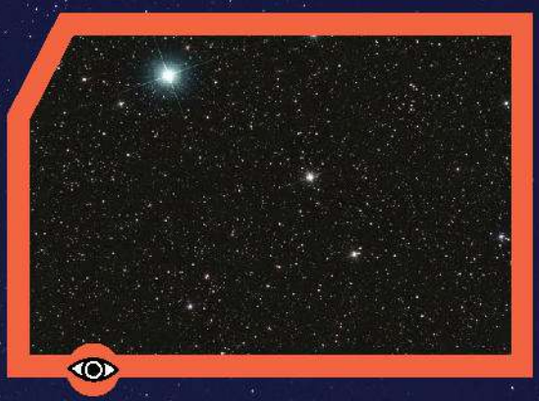
12 EAGLE NEBULA

Type of object: Star-forming region
Constellation: Serpens
Magnitude: +6.4
Right ascension: 18h 18m 48s
Declination: −13° 49'
Minimum optical aid: Binocular
How to find: From Messier 11, climb slightly to Beta Scuti and then follow the stars of Scutum round clockwise, passing through Alpha Scuti and arriving at Gamma Scuti. The Eagle Nebula forms the apex of an equilateral triangle with this star and HIP 89851. This region is home to the 'Pillars of Creation', where new stars are forming.



13 ALMACH

Type of object: Double star
Constellation: Andromeda
Magnitude: +2.3
Right ascension: 02h 03m 54s
Declination: +42° 19' 47"
Minimum optical aid: Binocular
How to find: This visible double star can be found in the leg of Andromeda. The duo appear as one golden and one blue star, although deeper observations have shown that the blue star is actually a triple-star system. When observing Almach, you get four stars for the price of one.



14 ALGOL

Type of object: Variable star
Constellation: Perseus
Magnitude: +2.1
Right ascension: 03h 08m 10.1s
Declination: +40° 57' 20.3"
Minimum optical aid: Unaided eye
How to find: This star is an eclipsing binary – two stars which from time to time block out some of each others' light from our perspective. You should be able to see its brightness change over time. Find it as the eye in the decapitated head of Medusa in Perseus, slightly down from Mirfak.

15 MESSIER 5

Type of object: Globular cluster
Constellation: Serpens
Magnitude: +5.6
Right ascension: 15h 18m 33.2s
Declination: +02° 04' 51.7"
Minimum optical aid: Binocular
How to find: Look up until you find the very bright red star Arcturus in Boötes. Messier 5 is located just above the rough halfway point of the line between them, and also creates a much shorter line with two stars in Virgo – 110 and 19 Virginis.

16 SATURN

Type of object: Planet
Constellation: Aquarius
Magnitude: +0.4
Minimum optical aid: Unaided eye
How to find: Saturn will reach opposition on 27 August in the constellation of Aquarius. A small telescope will begin to reveal Saturn's famous set of gleaming rings. You might even spy one of its 83 moons as a bright and distinctive spot near the gas giant itself.

17 LAGOON NEBULA

Type of object: Emission nebula
Constellation: Sagittarius
Magnitude: +4.6
Right ascension: 18h 03m 37s
Declination: -24° 23' 12"
Minimum optical aid: Binocular
How to find: Take the two stars on the left-hand side of the lid of The Teapot – Phi and Lambda Sagittarii – and extend that line upwards and you'll come to a region containing quite a few objects of note, including the Lagoon Nebula and Trifid Nebula.

18 ANDROMEDA GALAXY

Type of object: Galaxy
Constellation: Andromeda
Magnitude: +3.4
Right ascension: 00h 42m 44.3s
Declination: +41° 16' 9"
Minimum optical aid: Unaided eye
How to find: Gamma Cassiopeiae, along with Shedir and Caph, form an arrow that you can follow down to the Andromeda Galaxy. Or start with Mirach in Andromeda and climb upwards through Mu and Nu Andromedae. Binoculars can help in medium-level light pollution.

©NASA/ ESO / NOAO

19 MESSIER 3

Type of object: Globular cluster
Constellation: Canes Venatici
Magnitude: +6.4
Right ascension: 13h 42m 11.6s
Declination: +28° 22' 38.2"
Minimum optical aid: Binocular
How to find: From the bright star Arcturus in Boötes, head towards the star Cor Caroli in Canes Venatici. Just under halfway along this line is the globular cluster Messier 3. Along with Messier 13 in Hercules, it's considered one of the best globular clusters visible from the Northern Hemisphere.

20 WILD DUCK CLUSTER

Type of object: Open cluster
Constellation: Scutum
Magnitude: +6.3
Right ascension: 18h 51m
Declination: -06° 16' 12"
Minimum optical aid: Binocular
How to find: Return to Altair in Aquila (the Eagle), then pick out Delta Aquilae slightly to the lower right. Join the line between them and continue towards Lambda Aquilae. The constellation of Scutum and Messier 11 within it are about five degrees to the right.

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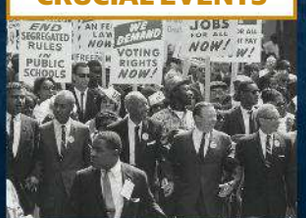	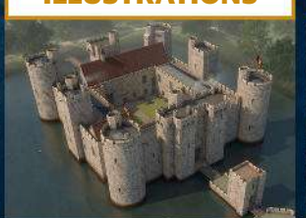	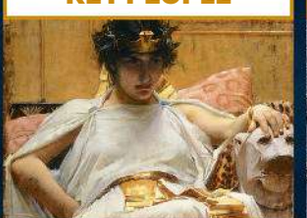		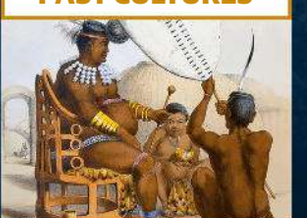

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WHAT'S IN THE SKY?

What to look out for during this observing period

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23 MAY
The Moon and Venus make a close approach, passing within 2°11' of each other in Gemini

24 MAY
The Moon and Mars make a close approach, passing within 3°39' of each other in Cancer

29 MAY
Mercury is at greatest elongation west, shining at +0.4 in the dawn sky

2 JUNE
The Great Globular Cluster (Messier 13) is well placed for observation in Hercules

3 JUNE
Mars and the Beehive Cluster (Messier 44) pass within 10.4' of each other in Cancer

3 JUNE
The Moon will pass in front of Delta Scorpii, creating a lunar occultation

3 JUNE
Globular cluster Messier 12 is well placed for observation in Ophiuchus

4 JUNE
Mercury reaches half phase (dichotomy) in the morning sky, shining at magnitude +0.0

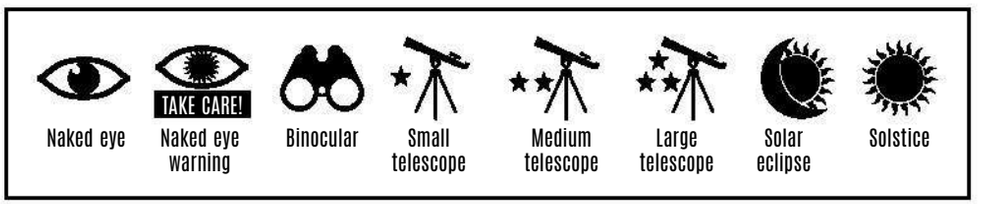
4 JUNE
Venus reaches half phase (dichotomy) in the evening sky, shining at magnitude -4.3

4 JUNE
Venus is at greatest elongation east, shining at magnitude -4.3 in the evening sky

6 JUNE
Asteroid 11 Parthenope will be well placed for observation in Ophiuchus

11 JUNE
Globular cluster Messier 92 is well placed for observation in Hercules

14 JUNE
Venus and the Beehive Cluster (Messier 44) pass within 47.9' of each other in Cancer



Red-light friendly
In order to preserve your night vision, you should read our observing guide under red light

6 JUNE
Globular cluster Messier 10 is well placed for observation in Ophiuchus

9 JUNE
The Moon and Saturn make a close approach, passing within 2°42' of each other in Aquarius

10 JUNE
Mercury reaches its highest point, shining brightly at +0.4 in the dawn sky

14 JUNE
The Moon and Jupiter make a close approach, passing within 1°22' of each other in Aries

"Venus is at greatest elongation east, shining at magnitude -4.3 in the evening sky"

Jargon buster

Conjunction
An alignment of objects at the same celestial longitude. The conjunction of the Moon and the planets is determined with reference to the Sun. A planet is in conjunction with the Sun when it and Earth are aligned on opposite sides of the Sun.

Declination (Dec)
How high an object will rise in the sky. Like Earth's latitude, Dec measures north and south in degrees, arcminutes and arcseconds. There are 60 arcseconds in an arcminute and 60 arcminutes in a degree.

Opposition
When a celestial body is in line with Earth and the Sun. During opposition, an object is visible for the whole night, rising at sunset and setting at sunrise. At this point in its orbit, the celestial object is closest to Earth, making it appear bigger and brighter.

Right Ascension (RA)
RA is to the sky what longitude is to Earth, corresponding to east and west. It's measured in hours, minutes and seconds, as since Earth rotates on its axis, we see different parts of the sky throughout the night.

Magnitude
An object's magnitude tells you how bright it appears from Earth, represented on a numbered scale. The lower the number, the brighter the object. A magnitude of -1.0 is brighter than +2.0.

Greatest elongation
When the inner planets, Mercury and Venus, are at their maximum distance from the Sun. During greatest elongation, the inner planets can be observed as evening stars at greatest eastern elongation and as morning stars during western elongation.

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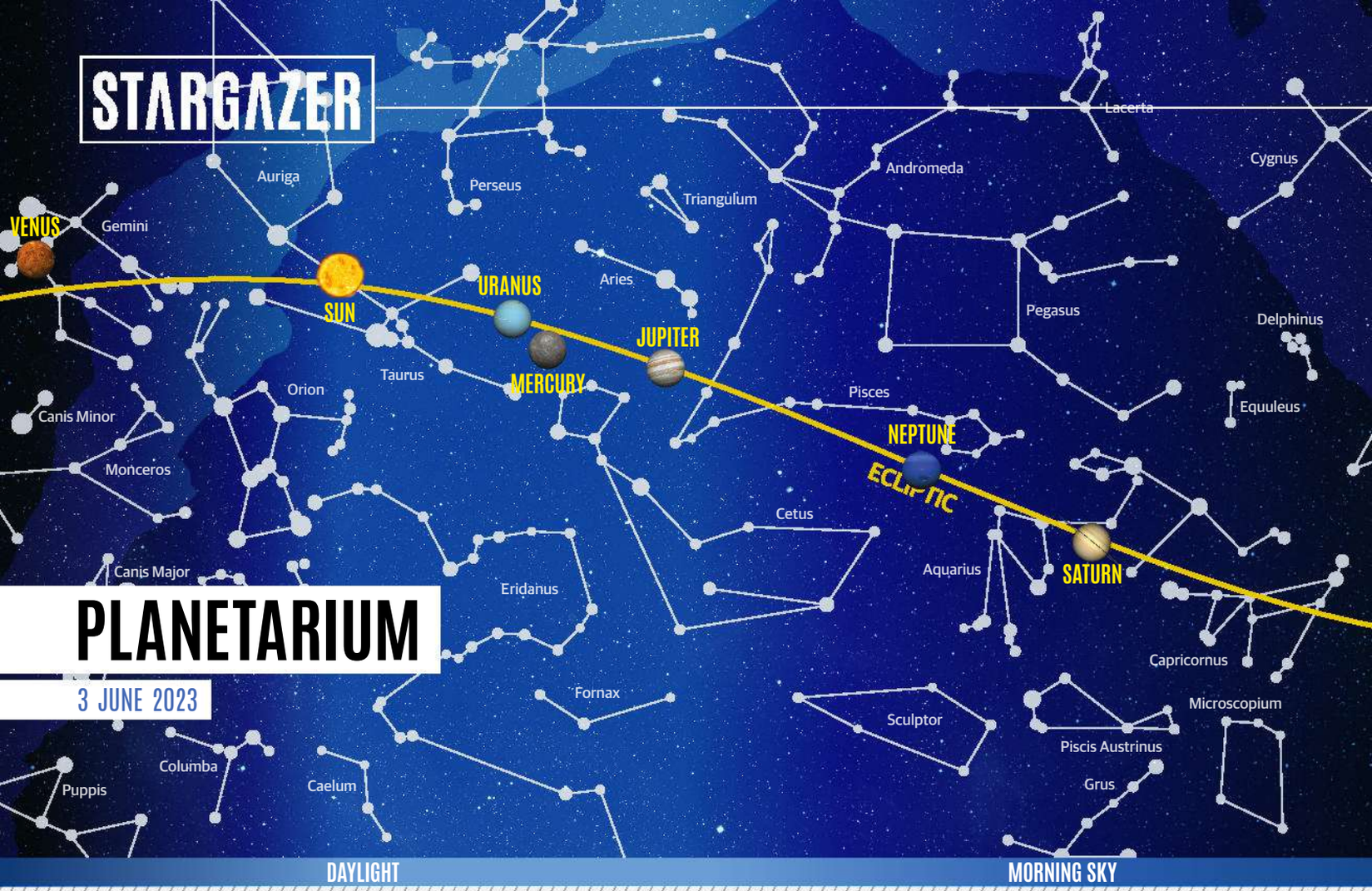


MOON CALENDAR

* The Moon does not pass the meridian on 3 June

19 MAY	20 MAY	21 MAY	22 MAY
NM			
0.1%	0.9%	3.9%	8.9%
04:43 21:09	05:06 22:26	05:38 23:35	06:21 --:--

23 MAY	24 MAY	25 MAY	26 MAY	27 MAY	28 MAY	29 MAY
				FQ		
15.5%	23.4%	32.2%	41.6%	51.3%	61.1%	70.7%
00:30 07:16	01:12 08:21	01:41 09:32	02:03 10:45	02:19 11:57	02:33 13:09	02:44 14:20

30 MAY	31 MAY	1 JUN	2 JUN	3 JUN	4 JUN	5 JUN
					FM	
79.6%	87.5%	93.8%	98.1%	--.--*	99.9%	98.8%
02:55 15:33	03:06 16:49	03:18 18:09	03:34 19:34	03:55 21:01	04:26 22:23	05:12 23:33

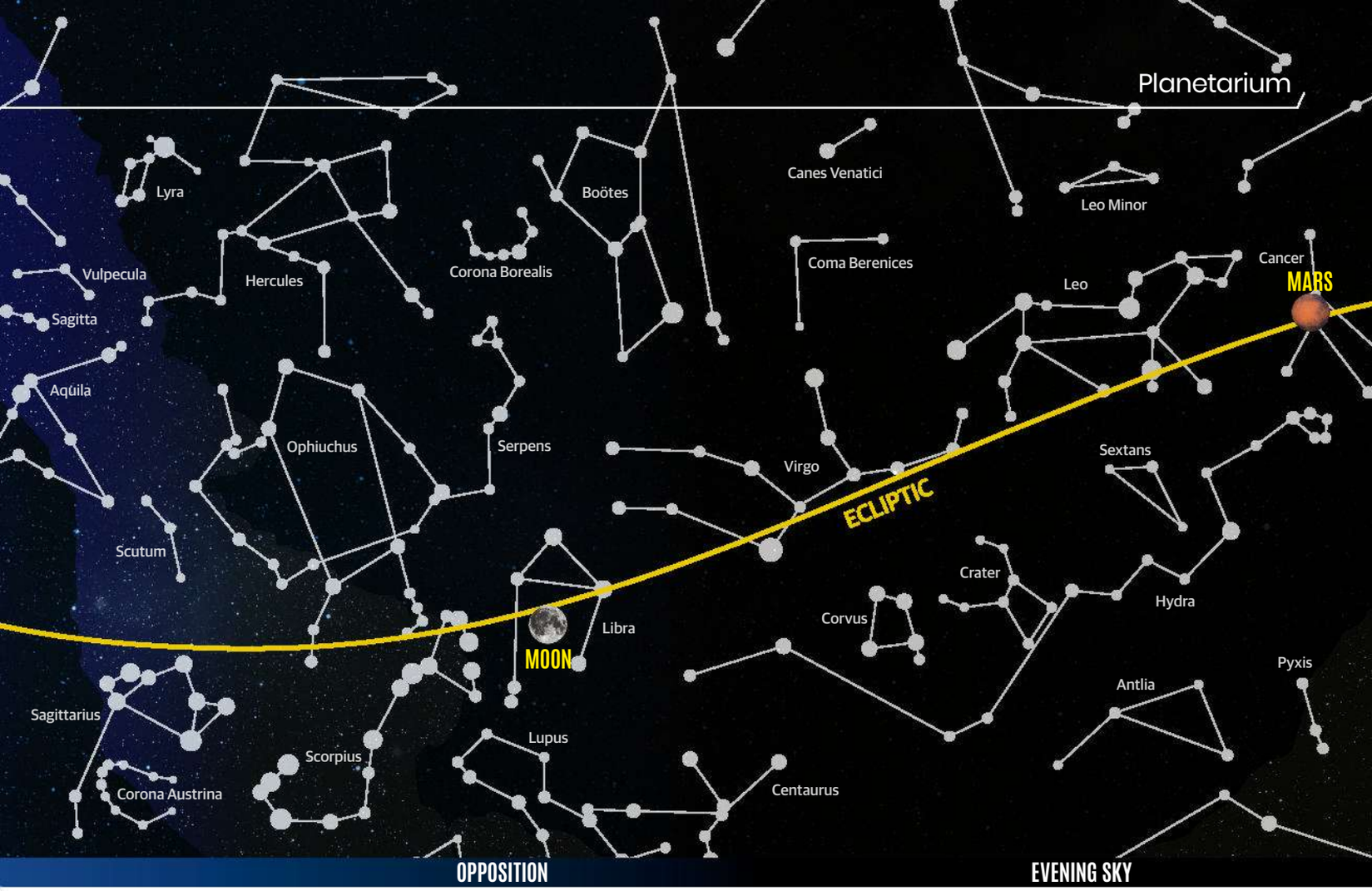
6 JUN	7 JUN	8 JUN	9 JUN	10 JUN	11 JUN	12 JUN
				TQ		
94.8%	88.0%	78.9%	68.2%	56.7%	44.9%	33.7%
06:16 --:--	00:23 07:38	00:58 09:08	01:22 10:39	01:39 12:06	01:53 13:29	02:06 14:51

13 JUN	14 JUN	15 JUN	16 JUN
23.5%	14.8%	8.0%	3.2%
02:18 16:11	02:32 17:32	02:48 18:52	03:09 20:10

% Illumination
Moonrise time
Moonset time

FM Full Moon
NM New Moon
FQ First quarter
TQ Third quarter

All figures are given for 00h at midnight (local times for London, UK)



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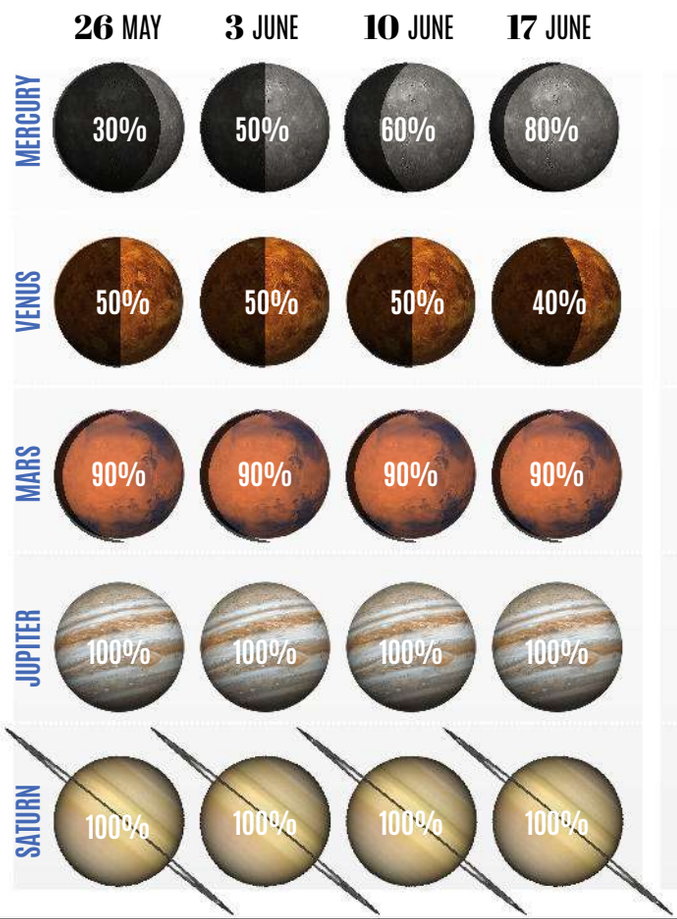


PLANET POSITIONS

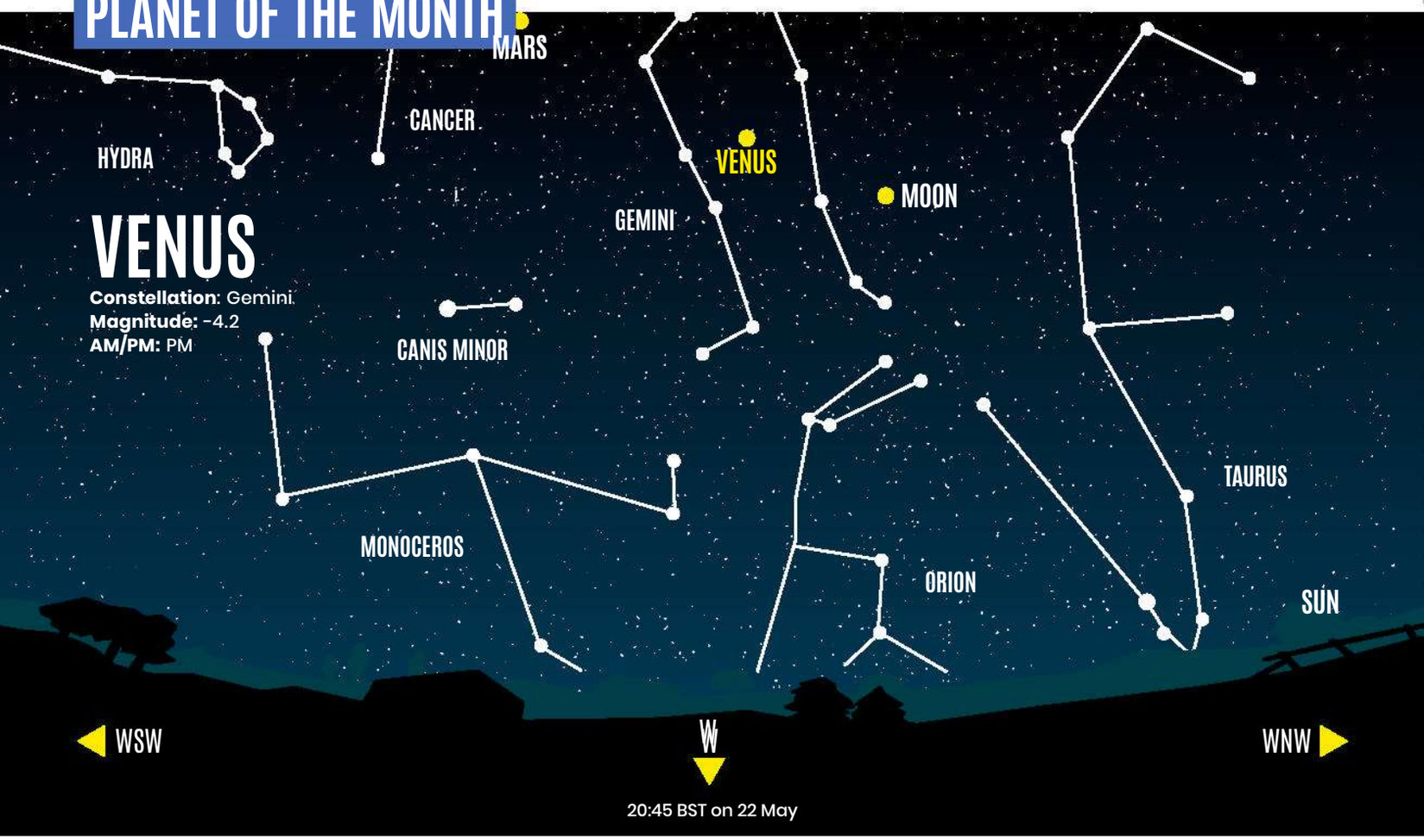
All rise and set times are given in BST

DATE	RA	DEC	CONSTELLATION	MAG	RISE	SET
19 MAY	02h 19m 25s	+10° 31' 48"	Aries	+1.5	04:35	18:32
26 MAY	02h 34m 26s	+11° 21' 40"	Aries	+0.7	04:18	18:24
3 JUNE	03h 05m 04s	+14° 02' 30"	Aries	+0.1	04:02	18:38
10 JUNE	03h 42m 48s	+17° 16' 59"	Taurus	-0.3	03:53	19:07
17 JUNE	04h 31m 12s	+20° 42' 04"	Taurus	-0.8	03:51	19:49
19 MAY	06h 53m 08s	+25° 40' 47"	Gemini	-4.2	07:31	00:42
26 MAY	07h 25m 00s	+24° 48' 01"	Gemini	-4.2	07:42	00:39
3 JUNE	07h 59m 14s	+23° 16' 07"	Gemini	-4.3	07:56	00:30
10 JUNE	08h 26m 48s	+21° 32' 45"	Cancer	-4.3	08:08	00:18
17 JUNE	08h 51m 45s	+19° 32' 56"	Cancer	-4.4	08:19	00:02
19 MAY	08h 04m 51s	+21° 58' 08"	Cancer	+1.5	09:10	01:26
26 MAY	08h 21m 35s	+21° 01' 52"	Cancer	+1.5	09:06	01:08
3 JUNE	08h 40m 39s	+19° 49' 57"	Cancer	+1.6	09:01	00:48
10 JUNE	08h 57m 16s	+18° 40' 41"	Cancer	+1.6	08:58	00:29
17 JUNE	09h 13m 48s	+17° 25' 47"	Cancer	+1.7	08:54	00:11
19 MAY	01h 53m 55s	+10° 32' 05"	Aries	-2.1	04:09	18:06
26 MAY	01h 59m 54s	+11° 04' 22"	Aries	-2.1	03:45	17:48
3 JUNE	02h 06m 35s	+11° 39' 26"	Aries	-2.1	03:17	17:26
10 JUNE	02h 12m 14s	+12° 08' 22"	Aries	-2.1	02:52	17:07
17 JUNE	02h 17m 40s	+12° 35' 35"	Aries	-2.2	02:28	16:47
19 MAY	22h 33m 57s	-10° 36' 59"	Aquarius	+1.0	02:40	12:57
26 MAY	22h 35m 07s	-10° 31' 49"	Aquarius	+1.0	02:13	12:31
3 JUNE	22h 36m 04s	-10° 28' 01"	Aquarius	+0.9	01:42	12:01
10 JUNE	22h 36m 36s	-10° 26' 35"	Aquarius	+0.9	01:15	11:34
17 JUNE	22h 36m 49s	-10° 26' 58"	Aquarius	+0.9	00:48	11:07

THIS MONTH'S PLANETS

Venus once again takes pride of place in the summer evening skies for observers

PLANET OF THE MONTH



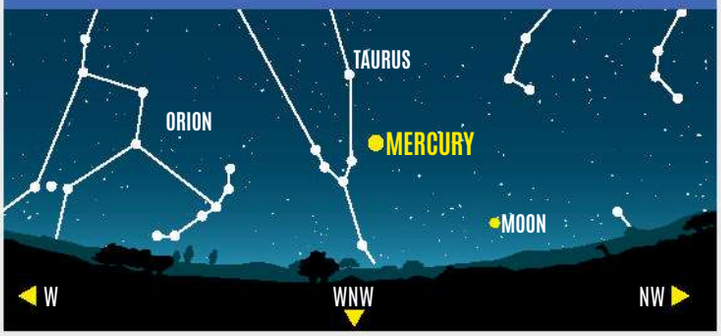
Another month when Venus is the Planet of the Month! Why? Not just because it is the brightest planet in the sky at the moment – although it will be strikingly bright to the naked eye all through the month ahead – and not just because it is so well-placed in the sky after sunset, either. It's because there will be a lot happening around it in the sky, such as conjunctions with other planets, and the Moon too, and because the announcement of an exciting new scientific discovery about this strangely familiar but totally alien world has put it in the news.

During the month ahead Venus will be a very beautiful evening star indeed. In mid-May it will be positioned in Gemini, beneath the constellation's bright twin stars, Castor and Pollux. It will set around four hours after the Sun, and as darkness falls will look like a vivid silvery spark in the west, shining to the lower right of much fainter, redder-hued Mars. Look to the north-west after sunset on 22 May and you'll see a spectacularly thin crescent Moon shining very close to Venus, down to its lower right. If you look at this conjunction through binoculars you should also be able to see the faint lavender glow of 'Earthshine' illuminating the dark face of the Moon inside the crescent.

On 4 June Venus leaves Gemini, crossing over into neighbouring Cancer and heading towards the famous 'Beehive' star cluster. Every day after that Venus will edge a little closer to the cluster, and after dark on the evening of 13 June it will actually pass through the outer edge of the cluster. This will be a stunning sight, especially with Mars shining just a short distance away from Venus at the same time. But by now Venus will be setting only two and a half hours after the Sun, so you won't have as long to see it as you did at the start of the month.

Venus hit the headlines back in March, when NASA scientists announced that they had found compelling evidence to suggest that there might be active volcanoes on Venus. Studying old Magellan probe radar images they noticed that a crater-like feature on a volcano had changed shape and size between different orbits of Magellan, suggesting the volcano had either erupted or the feature had collapsed in on itself as lava burned beneath it. Future space missions will seek to confirm these observations, and prove, once and for all, if Venus is still an active planet today.

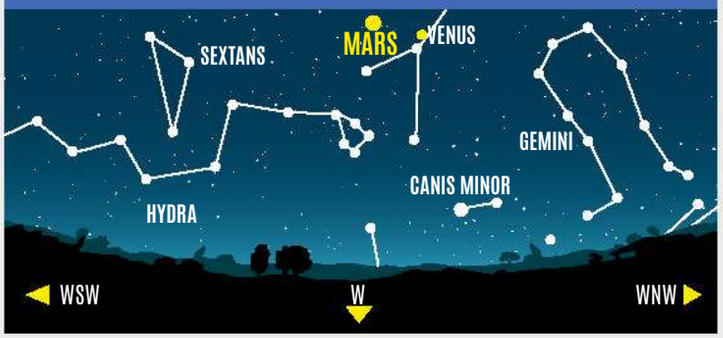
MERCURY 18:30 BST on 15 June



Constellation: Aries **Magnitude:** +1.6 **AM/PM:** AM

At the start of our observing period Mercury will be rising so shortly before sunrise that it won't be visible, but by 1 June it will be rising almost half an hour before the Sun so you might just catch sight of it. By 15 June, Mercury will be rising 40 minutes before sunrise, and its brightness will have grown to -0.7, making it easier to see.

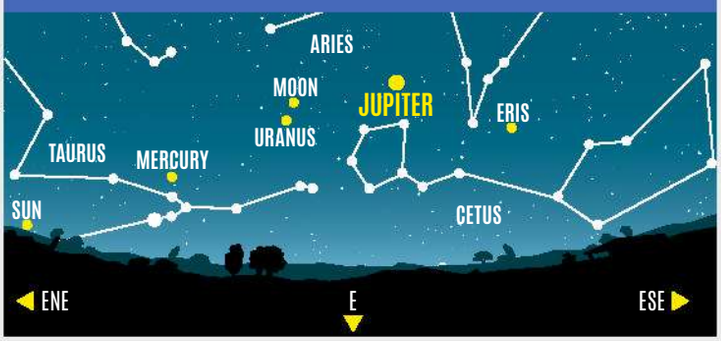
MARS 20:30 BST on 15 June



Constellation: Cancer **Magnitude:** +1.5 **AM/PM:** PM

Mars will be an orange evening star this month, bright enough to be easily visible to the naked eye. In mid-May it will be found on the border between Cancer and Gemini. As the days pass Mars will edge closer to Messier 44 until it will be smack in the middle of this star cluster on the evening of 2 June, a lovely sight in binoculars.

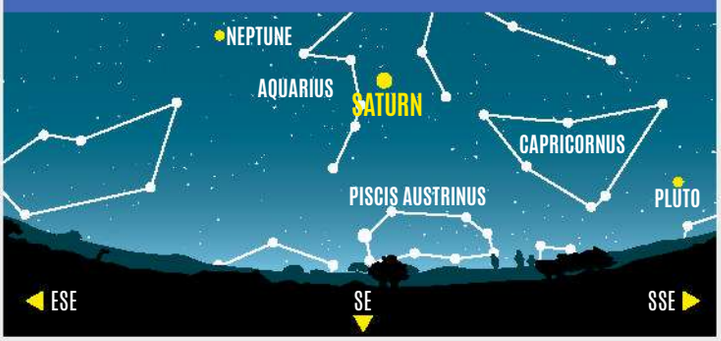
JUPITER 05:30 BST on 15 June



Constellation: Pisces **Magnitude:** -2.1 **AM/PM:** AM

At the start of our observing period Jupiter will be a bright morning star, rising in the east around half an hour before the Sun. By 15 June Jupiter will be rising more than 90 minutes before the Sun, making it visible in a reasonably dark sky, and even a pair of binoculars will be powerful enough to show you up to four of its family of moons.

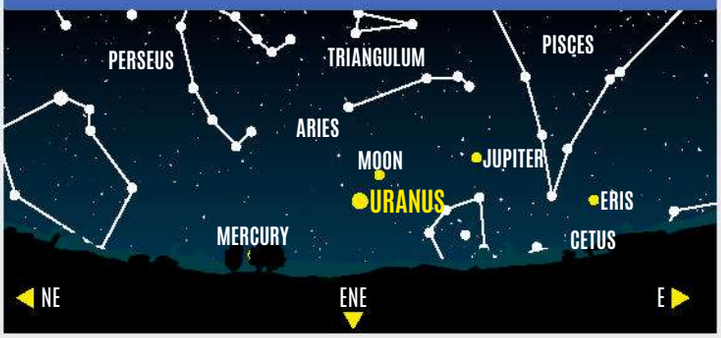
SATURN 05:30 BST on 15 June



Constellation: Aquarius **Magnitude:** +1.0 **AM/PM:** AM

Saturn will be a morning star all through the month ahead, but it will not be strikingly obvious to the naked eye. By 15 June Saturn will be much easier to see, as it will be rising almost three hours before the Sun. You will need a telescope to see those famous rings, but binoculars will show you its Mercury-sized moon Titan.

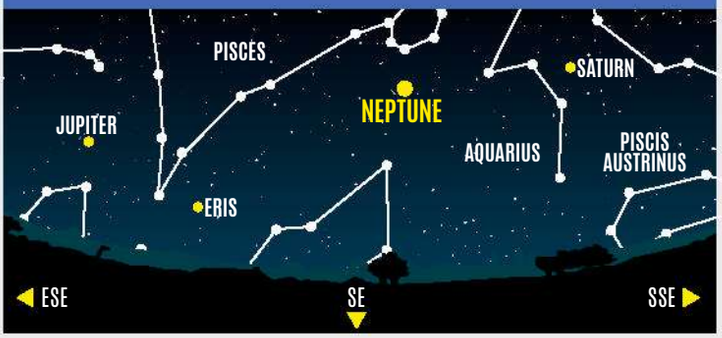
URANUS 04:00 BST on 15 June



Constellation: Aries **Magnitude:** +5.9 **AM/PM:** AM

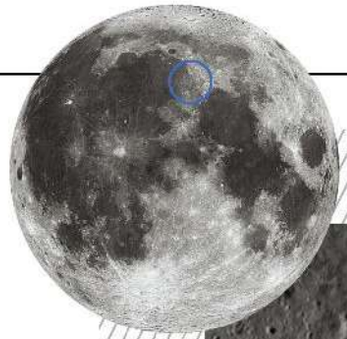
You probably won't see Uranus at all until the middle of June; before then it will either be too close to the Sun or in too bright a sky to be seen. By 15 June Uranus will be rising over an hour before the Sun, but very challenging to see in such a bright sky. Through binoculars you might see it as a faint greenish star very close to the Moon.

NEPTUNE 04:00 BST on 15 June



Constellation: Pisces **Magnitude:** +7.9 **AM/PM:** AM

This month Neptune's low brightness and its position in the bright morning sky will make it very hard to observe. By the middle of June it will rise three hours before the Sun, so you should be able to track it down then if you know exactly which starry speck of light in Aries it is. But really it will be better to wait until later in the year.



MOON TOUR

CASSINI CRATER

Use summer's clear nights to find a lunar crater named in honour of one of astronomy's most respected planetary observers

The Moon's 'celebrity' craters attract lots of attention because they are so easy to spot and are dramatic in an eyepiece. But the smaller, less dramatic craters – the ones without huge mountain peaks jabbing up from their centres or bright rays of debris surrounding them – can be just as fascinating if you take the time to get to know them.

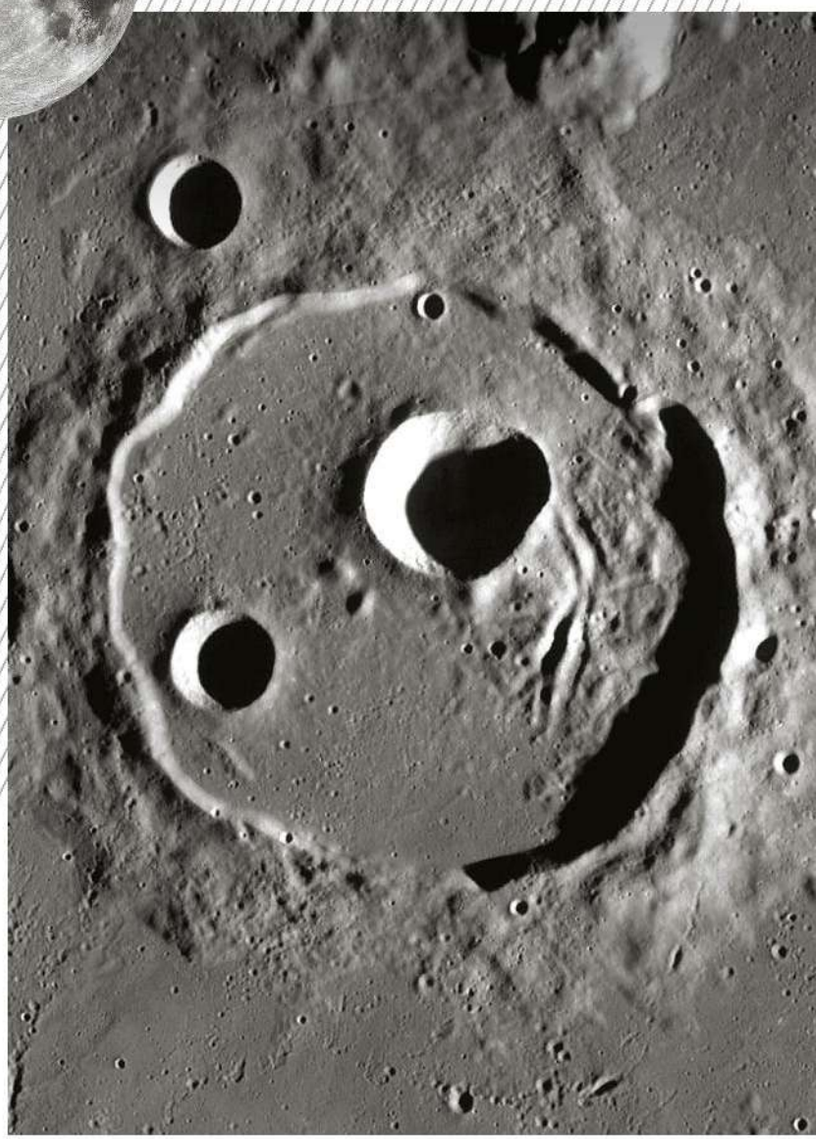
One such crater is Cassini, which is perhaps the only noteworthy feature in the unremarkable lunar plain known as Palus Nebularum, just to the south of the Alpine Valley. As you might have guessed, Cassini was named after astronomer Giovanni Cassini, who, in 1675, was the first to observe the widest gap within Saturn's rings, later named the Cassini Division in his honour. In addition, Cassini discovered four of Saturn's major moons – Iapetus, Tethys, Rhea and Dione – and also observed markings on Mars, too. So it was no surprise when the Cassini probe, which has been orbiting Saturn since 2004, was named after him.

The Cassini crater is just 57 kilometres (35 miles) wide with a lava-flooded floor. However, the crater floor is not flat; a pair of smaller craters (Cassini A and B) have been blasted out of its floor by impacts, and several much smaller craters spatter Cassini's interior. While B is unremarkable, A is quite an impressive crater in its own right – it's a deep, steep-sided oval pit some 15 kilometres (nine miles) wide, with an area of jumbled, hummocky terrain to its east, ploughed up by the impact which caused it.

Cassini's walls are narrow and low, without any of the complicated terracing or ledges seen in the walls of those 'celebrity' craters like Copernicus and Tycho, and some observers think they make it look like a ring dropped on the surface of the Moon. Using high magnification to view Cassini on a still night will show that the crater sits on top of a broad rampart of ejecta material, like a castle standing on top of a low hill.

So, when can you see it? As this issue hits the shelves the Moon will be new, making Cassini hard to see. Too small to see with the naked eye at any time, a pair of binoculars might just show it as a small, light ring to the lower right of the dark oval of Plato. But if you wait until 25 May when the terminator sweeps away from it, its walls and craters will be much more obvious.

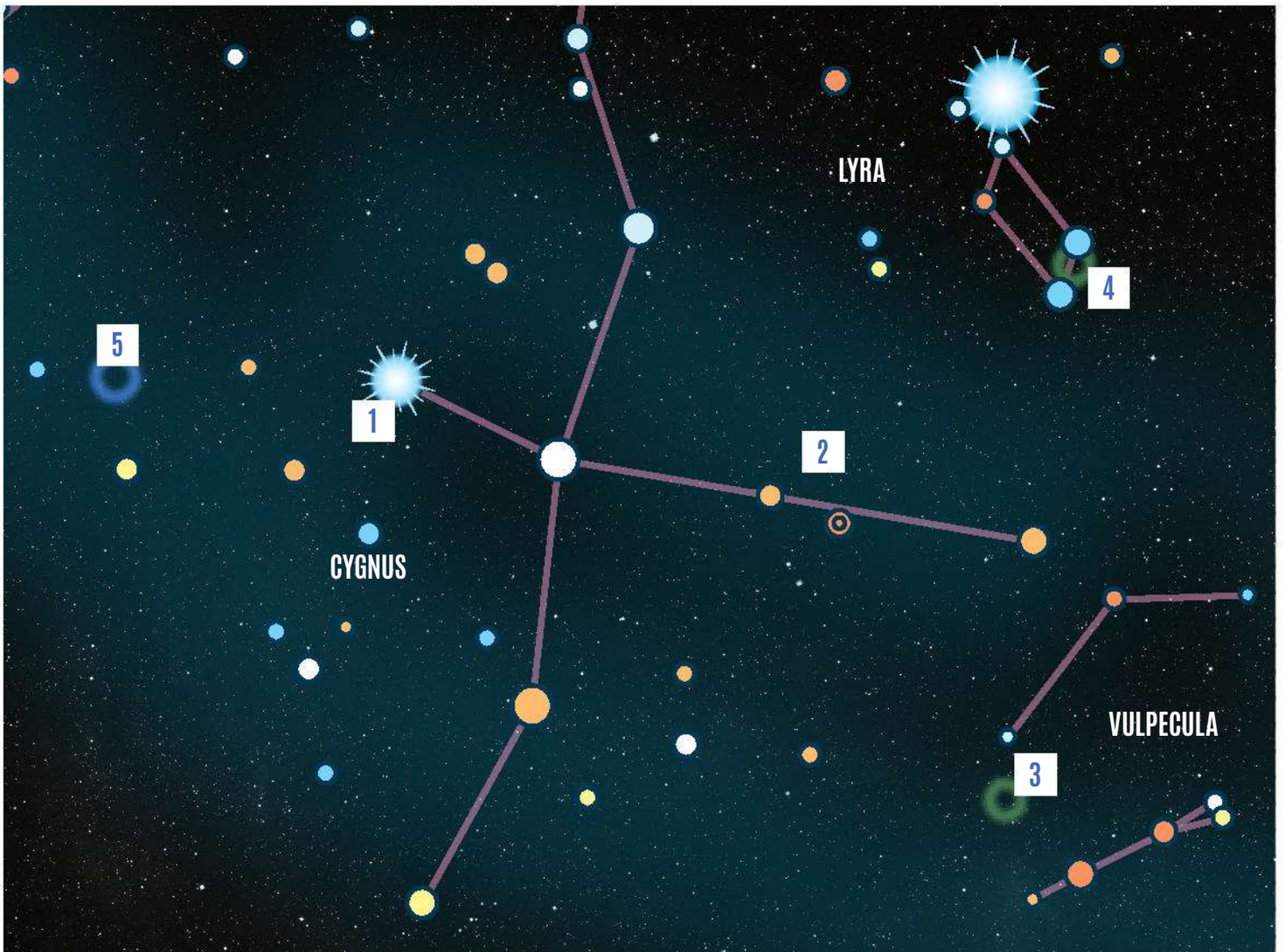
We lose sight of it as the Moon heads towards its full phase, but Cassini will make a dramatic spectacle around 6 June when the Moon is at a waning gibbous. Then you have a few days to spot craters A and B nestling inside Cassini's walls, before the terminator sweeps over it, plunging the feature into darkness.



TOP TIP!

The Moon can be a dazzling sight through a telescope, so don't look at it for longer than a couple of minutes at a time. Use a Moon filter to cut down any glare and improve contrast.

© NASA; Source: Wikipedia Commons/Public Domain



NAKED EYE AND BINOCULAR TARGETS

The summer night sky is bright, but if it's clear you can still see shells of gas billowing away from dying suns and a glittering cloud of stars

1 Deneb (Alpha Cygni)

The brightest star in Cygnus but only the 19th brightest in the sky, Deneb is a blue supergiant star so huge it would swallow Earth if put in the Sun's place. Some 2,600 light years away, it's roughly 20,000 times more luminous than our Sun.

2 Cygnus X

Look down the right side of the 'Northern Cross' and you'll see a long, fuzzy area. This is the Cygnus star cloud, and binoculars reveal it's made of countless millions of faint stars. When looking at it we are staring down a neighbouring spiral arm in our galaxy, the Milky Way.

3 Dumbbell Nebula (Messier 27)

Also known as Messier 27, the Dumbbell can be seen with binoculars as a very small smudgy spot. It's 1,360 light years away and is a ghostly shell of material expelled from an ancient star in the last stages of its life.

4 Ring Nebula (Messier 57)

At magnitude +8.8, the Ring Nebula is so faint you'll need binoculars to see it. Even then it will merely look like a tiny out-of-focus star. Over 2,000 light years away, like Messier 27 it's a shell of glowing gases puffed out by a dying star.

5 Messier 39

Messier 39 is a large open cluster 1,063 light years from Earth and seven light years across. It contains around 30 stars. At magnitude +5.5 it's visible to the naked eye as a Moon-sized faint smudge in a dark sky, but binoculars will show its triangular shape more clearly.

1 Messier 56

DEEP SKY CHALLENGE

A GAGGLE OF GLITTERING GLOBULAR CLUSTERS

Messier 13 in Hercules isn't the only stellar gathering to see in the summer sky

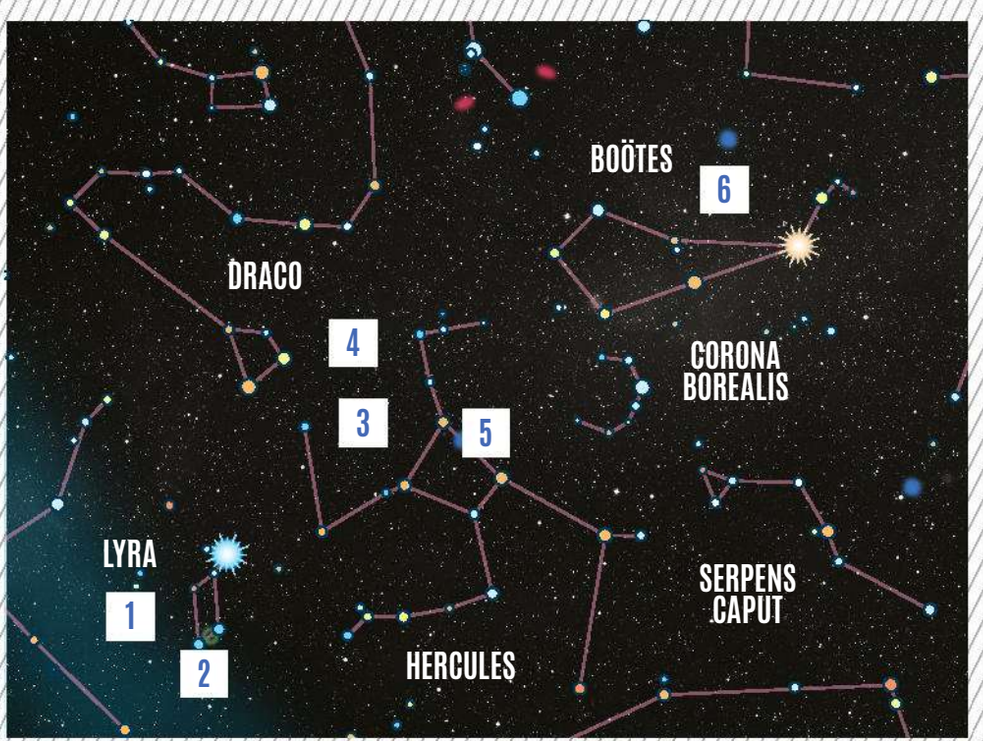
As spring slides into summer, the brightness of the night sky makes observing deep-sky objects quite a challenge. The misty nebulae and smoky galaxies that fill our eyepieces on the long, frosty nights of darker seasons become washed out by the lingering twilight. Fortunately, there are plenty of other deep-sky objects to track down and observe.

Globular clusters are enormous, spherical groups of tens or even hundreds of thousands of stars, but because they are so far away they only appear as small, round smudges in our telescopes. The most famous globular in the northern sky is Messier 13, the Great Globular Cluster in Hercules. It's surrounded by many others that are well worth an observer's attention on a clear night at this time of year, but suffer from being in its shadow – if the beautiful Messier 92 was in another part of the sky it would be much more popular, but with Messier 13 just a short star hop away, it's overlooked.

Also visible at this time of year is Messier 57, the Ring Nebula. Although it's brighter than many of the other objects on this month's list, your challenge is to detect its subtle pastel colours and the faint star at its centre.

5 Messier 13

3 Messier 92



1 Messier 56

This eighth-magnitude globular cluster is roughly spherical. In a high-power eyepiece you'll see an attractive mix of faint blue and red stars, with a triangle of brighter stars embedded in its western edge.

2 The Ring Nebula (Messier 57)

The most popular planetary nebula in the northern sky, you'll need to be under a very dark sky and using a large telescope to see its blue and green colours and the faint star in its centre.

3 Messier 92

This sixth-magnitude globular cluster is a very rich, condensed ball of blue-white stars. Almost perfectly symmetrical, it's a beautiful sight in any telescope, but is sadly overshadowed by the much larger and brighter Messier 13 nearby.

4 NGC 6229

This little-known tenth-magnitude globular cluster is 99,000 light years away. High magnification is needed to reveal its condensed core of pollen-grain grey-blue stars surrounded by a cage of brighter yellow stars.

5 Great Globular Cluster in Hercules (Messier 13)

The finest cluster in the northern sky, Messier 13 is a spectacular sight in a large telescope: a beautiful ball of glittering blue-white stars with strands of fainter stars spraying from its outer edges.

6 NGC 5466

With no central condensation, this small, tenth-magnitude object looks more like an open cluster than a globular cluster. Looking at it under high power, you'll be reminded of a miniature version of Messier 44, the Beehive Cluster.

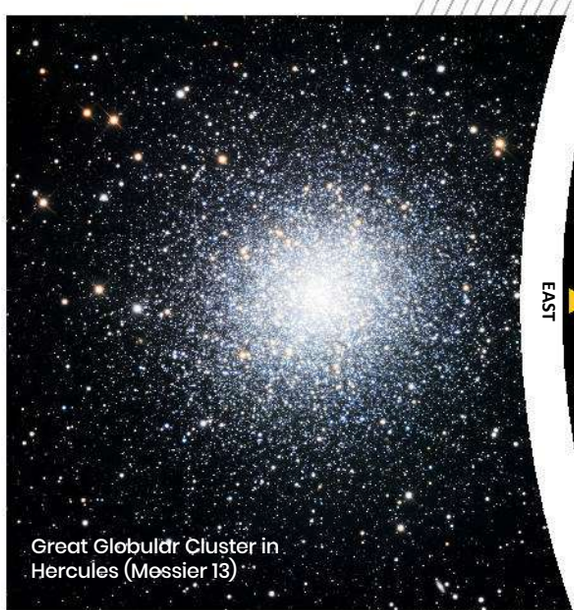
©: NASA, Hubble; ESA; Getty Images

NORTHERN HEMISPHERE

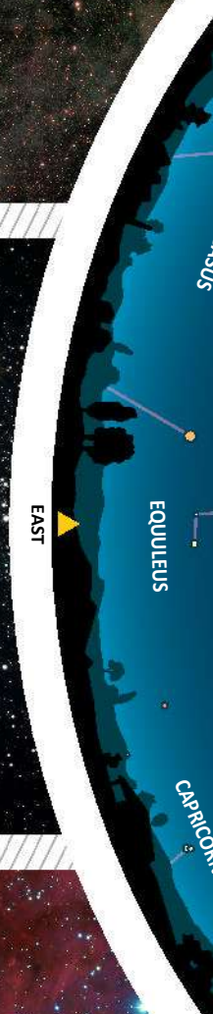
This month, astronomers have a selection of targets at their fingertips

Lyra, Aquila, Hercules, Sagittarius, Scorpius and Ophiuchus are within easy reach this month, packed with objects. Head over to the Scorpion to take in views of the Blue Horsehead Nebula (IC 4592) and the Cat's Paw Nebula (NGC 6334). Fans of tight-knit globular star clusters should turn their attention to Ophiuchus and Hercules, where they will be rewarded with sights of the extremely stellar-rich Messier 10, Messier 12, Messier 13, Messier 14 and Messier 92. Astrophotographers will get great enjoyment from the binary star system Rho Ophiuchi, which is surrounded with a red emission nebula and very impressive dust lanes. Cygnus is another gold mine, with the Veil Nebula, Fireworks Galaxy and the Crescent Nebula all excellent choices.

The Blue Horsehead Nebula (IC 4592)


Great Globular Cluster in Hercules (Messier 13)

The Cat's Paw Nebula (NGC 6334)



Using the sky chart

This chart is for use at 22:00 mid-month and is set for 52 degrees latitude.

1. Hold the chart above your head with the bottom of the page in front of you.
2. Face south and notice that north on the chart is behind you.
3. The constellations on the chart should now match what you see in the sky.

Magnitudes

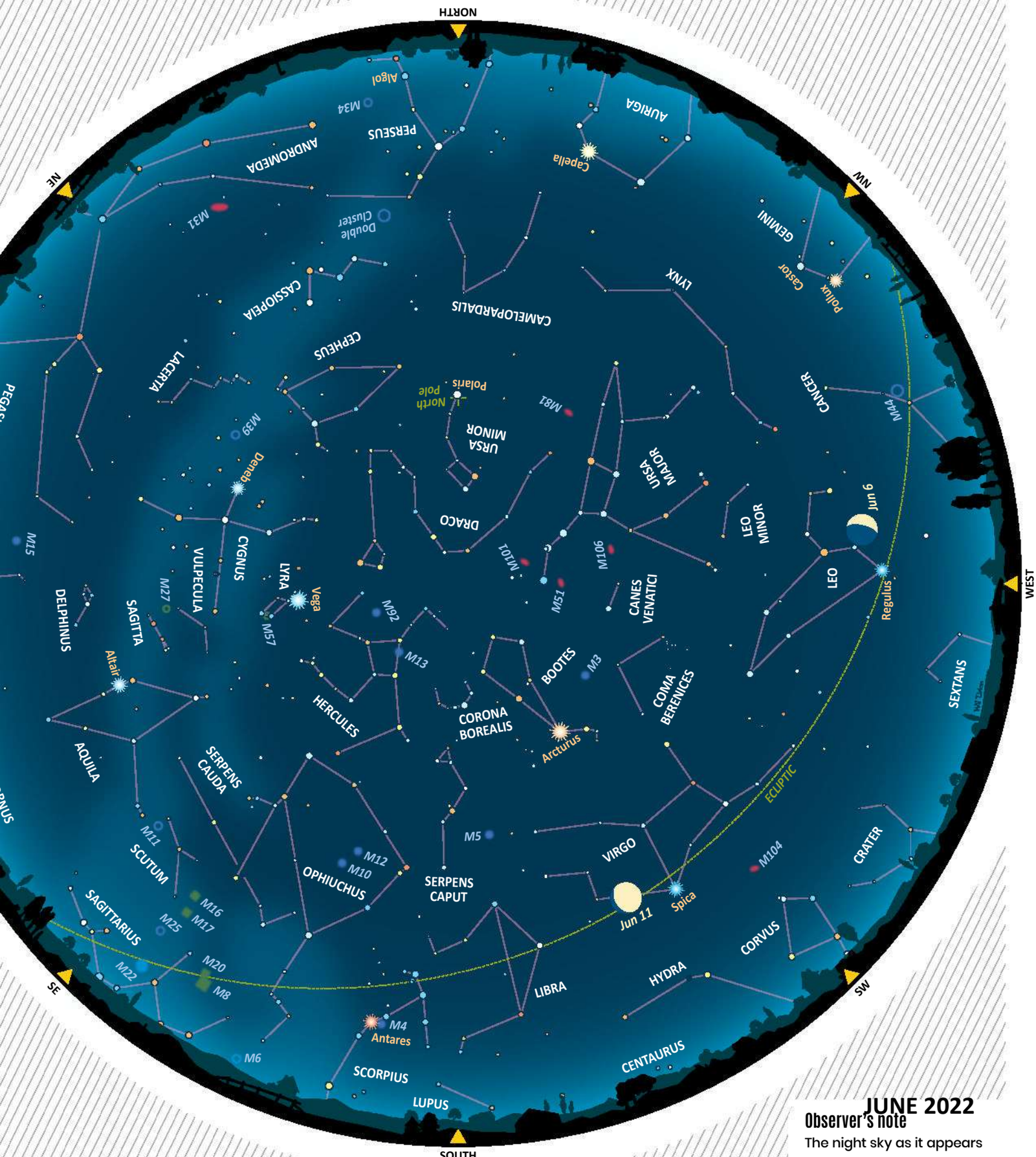
- Sirius (-1.4)
- -0.5 to 0.0
- 0.0 to +0.5
- +0.5 to +1.0
- +1.0 to +1.5
- +1.5 to +2.0
- +2.0 to +2.5
- +2.5 to +3.0
- +3.0 to +3.5
- +3.5 to +4.0
- +4.0 to +4.5
- Fainter
- Variable star

Spectral types

- O–B
- A
- F
- G
- K
- M

Deep-sky objects

- Open star clusters
- Globular star clusters
- Bright diffuse nebulae
- Planetary nebulae
- Galaxies



JUNE 2022

Observer's note

The night sky as it appears on 17 June 2023 at approximately 22:00 (BST)

© Getty

Image contrast through the Nikon Travelite EX 8x25 binocular seemed a bit better than Nikon's Prostaff P7 8x42

REVIEW

NIKON TRAVELITE EX 8x25

Though too small for serious skywatching, this miniature binocular nevertheless provides nice views of the night sky for the casual stargazer

Reviewed by Gemma Lavender

BINOCULAR ADVICE

Magnification: 8x

Objective lens diameter: 25mm

Angular field of view: 6.2 degrees

Eye relief: 15.5mm

Weight: 355 grams

ADDITIONAL KIT

- Carrying case
- Neck strap
- Double eyepiece cover

The Nikon Travelite EX 8x25 binocular is an ostensibly multi-purpose daytime binocular, so if you're out and about on a nature walk, at a sporting event or just doing some sightseeing, these are perfect. However, when the Sun sets and the night comes, how do they perform? Normally 10x50 binoculars are recommended for skywatching, and the 25mm aperture of the Nikon Travelite binocular is just half the diameter. We weren't expecting a great performance from this binocular when we pointed it at the stars, but we were pleasantly surprised.

The binocular features winding eyecups with a reasonably large range of movement, providing 15.5 millimetres (0.6 inches) of eye relief, making these usable for spectacle wearers. We found we had to wind the eyecups out, otherwise the view appeared partly obscured. Focusing is smooth thanks to a central dial. Although our review model didn't come with any accessories, the binocular does come with a carry case that can attach to your belt, a double eyepiece cover and a neck strap. The field of view of the binocular at 1,000 metres (3,281 feet) is 110 metres (361 feet). Since 17.5 metres (57.4 feet) at a distance of 1,000 metres corresponds to one degree in the night sky, the binocular gives an angular field of view of 6.2 degrees. The angular size of the full Moon in the sky is about half a degree, so in other words the field of view of the Nikon Travelite EX 8x25 binocular is 12 full Moon widths.

Indeed, when we looked at the Moon it was a five-day-old waxing crescent, and the

Moon appeared fairly small in the field of view. We could see plenty of craters, most notably on the terminator between lunar day and night, where the interplay of light and shadow is at its greatest. We could also make out craters on the illuminated portion of the lunar surface, where the brightness usually affects contrast. In fact, the image contrast through the Nikon Travelite EX 8x25 binocular seemed a bit better than that of the Nikon Prostaff P7 8x42 that we were also testing, with the crater rims better defined.

The fairly large field of view was further brought home when we shifted southeast from the Moon in Taurus (the Bull) to the constellation of Orion (the Hunter). The three belt stars, called Alnitak, Alnilam and Mintaka, all fit into the field of view, while in the background were many faint pinpricks of light from fainter stars invisible to the unaided eye. Views of the stars were highly defined and sharp.

When viewed through Nikon's Prostaff P7 8x42 or Celestron's UpClose G2 10x50 binoculars that we also had at our disposal, these background stars appeared far more prominent to us, as would be expected from the larger light grasp of the bigger barrels. When looking at Orion's Belt, we could also squeeze in the fuzzy glow of the Orion Nebula (Messier 42) at the bottom of the field. The Nikon Travelite EX 8x25 binocular was able to make out some of the stars of the Trapezium Cluster, though again not as many as the larger binoculars.

Despite the lack of light-gathering power, sweeping through the dusty track of the Milky Way revealed stunning views filled with stars. The viewing was a pleasant and comfortable observing experience, the binocular being so light that we barely noticed we were holding it. There's virtually no shake affecting the view, unlike the wobbly arm syndrome that can affect stargazing through larger but heavier handheld binoculars, thanks to the featherweight and large field of the Nikon Travelite EX 8x25. Meanwhile, we discovered that the eye-relief adjustment and focusing were both super-smooth.

BEST FOR...

- £ MEDIUM BUDGETS
- CASUAL ASTRONOMERS
- LUNAR OBSERVING
- BRIGHT DEEP-SKY TARGETS
- PLANETARY OBSERVING

"We could also make out craters on the illuminated portion of the lunar surface, where the brightness usually affects contrast"

The binocular features winding eyecups with a reasonably large range of movement, providing 15.5 millimetres (0.6 inches) of eye relief

Focusing is smooth thanks to a central dial, but the aperture of these binoculars is too small for serious skywatching

We weren't expecting a great performance from this binocular when we pointed it at the stars, but we were pleasantly surprised

"Jupiter's moons were on the edge of perception in the Nikon Travelite EX 8x25 binoculars"

The binocular is waterproof for five minutes up to a depth of two metres (6.5 feet), which you're never going to need to worry about while stargazing. Perhaps more importantly, O-ring seals and nitrogen gas within the optical system prevent fogging – a design feature that we were massively impressed by as we moved from the warmer indoor temperatures into the chillier outdoors.

As nice as this binocular is, it's hard to get away from the fact that you can buy larger binoculars for a similar price, or at least not much more. The extra aperture really does make a difference for astronomy, as it allows you to see more detail and a wider selection of targets. For example, Jupiter's moons were on the edge of perception in the Nikon Travelite EX 8x25 binoculars, but a pair of 10x50s or larger show them clearly.

Saturn was not on show during our testing period, but the Nikon Travelite EX 8x25 binoculars would not be sufficient to show its rings clearly, nor its largest moon Titan, due to the small aperture of 25mm. Open star clusters are exquisite through the field of view, but the lower light grasp means they don't pop the way they did through the optical system of the Nikon Prostaff P7 8x42.

If you're looking for a pocket-sized all-rounder to engage in some casual observing with then the Nikon Travelite EX 8x25 binoculars are an excellent choice, but if you're planning on using binoculars as your main observing instrument then you'll very quickly find the need for much larger binoculars.

FOR

- ⊕ Pin-sharp crystal clear images
- ⊕ Compact design, suitable for travel
- ⊕ Wide field of view

AGAINST

- ⊖ Aperture too small for much astronomy
- ⊖ Expensive, can get larger binoculars for a similar price

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IN THE SHOPS: STAR TRACKERS

The best equipment for gazing at the night sky

Best overall tracker

Benro Polaris

Cost: £1,090 / approx. $1,358
From: Clifton Cameras

1 While most star trackers are a compromise between their own weight and their payload, the Benro Polaris is an exception – it is both super lightweight at 1.5 kilograms and super-supportive, taking a mighty seven kilograms of gear, the highest carrying capacity of any star tracker mount so far. It is the first star tracker to offer built-in DSLR control which allows you to adjust the composition of your photo remotely, and a built-in micro SD card slot. Remarkably, the Benro Polaris can even be controlled via the cellphone network. Its huge 2500 mAh battery can be recharged via USB-C while alignment is via any subject from a choice presented on a smartphone app. However advanced the best star trackers appear, there's evidence from this electric tripod head that their days are numbered. All of this top-quality tech does come at a high price though, sitting a little over £1,000.

Best for deep-sky astrophotography

iOptron SkyGuider Pro

Cost: £369 / $460
From: First Light Optics

2 The priciest yet one of the best star trackers around for astrophotographers is the iOptron SkyGuider Pro. Many star trackers are made for landscape photographers wanting to save on weight when out in the field searching for wide-angle compositions that include the night sky. But there are plenty of astrophotographers that only want to use telephoto lenses to capture light from distant deep sky objects. That means bigger payloads and longer exposures, which is what the iOptron SkyGuider Pro is designed for. Able to take about five kilograms, it can support long lenses or even a small telescope. Aligning using its electronic polar finderscope and iOptron Polar Scope app is simple, and like most of its rivals it also tracks the Sun, Moon and allows 1/2-speed motion time lapses at night.

Best for heavier cameras

Sky-Watcher Star Adventurer Mini

Cost: £289 / $360
From: First Light Optics

3 The incessant creep of light pollution means it's now almost inevitable that you'll need to travel to find the darkest night skies possible. That necessitates a star tracker that strikes the right balance between its own weight – because you'll need to carry it – and what it can support. Cue the Sky-Watcher Star Adventurer Mini, which can take a payload of three kilograms yet it is relatively easy to squeeze into a camera bag. It's not the sleekest device ever, and nor is its SA Console app up to much. However, once you get used to its minor niggles, the Star Adventurer Mini is reliable and relatively easy to use. It's possible to get accurate long-exposure images of up to about four minutes,. Accessories include a counterweight and declination bracket to increase the payload.

5

4

6

"it's suitable for those wanting to carry a star tracker in their camera bag during trips and travel"

Best value star tracker

Move Shoot Move

Cost: £160 / $199
From: Stellar Xperiences

4 Even smaller and more nimble than the SAM is the excellent value Move Shoot Move, a star tracker suitable only for wide-angle lenses. That's partly because of its limited payload of three kilograms and partly because it's just not the most accurate star tracker around. While that might sound like a deal-breaker, it's a plus if you only intend to take wide-angle images of the Milky Way and starfields. For such photos a rough alignment with Polaris is all you need, something that can be done easily and quickly using an included green laser pointer. The Move Shoot Move isn't going to accurately track Polaris for more than two or three minutes – though the wider and lighter your lens you use, the longer it will remain accurate. But none of that will matter much if you have a reasonably fast wide-angle lens. If you have a telephoto lens though, look elsewhere.

Best for small cameras

Vixen Polarie

Cost: £395 / $492
From: Rother Valley Optics Ltd

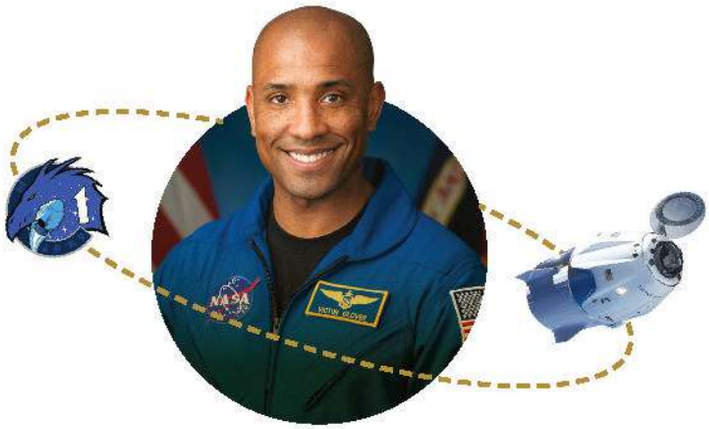
5 In the world of star trackers, there's always a trade-off between size and versatility, and the Polarie compact size means it can support a payload of just two kilograms. Therefore, it is best used with not only wide-angle lenses but fairly lightweight models – using a mirrorless camera body will give you more flexibility. Alignment is via a supplied compass, a built-in latitude metre and a polar sight hole, so you will have to know how to find Polaris and/or the south celestial pole. On hand to help are both red light illumination and the Vixen PF-L Assist app for smartphones, and you can have a look at our handy guide too. As well as long exposure astrophotography the Polarie can track the Moon and the Sun and its half-speed allows motion time-lapses at night. Its short two-hour battery life can be augmented by instead attaching a power bank to its micro USB slot.

Best for travel

iOptron SkyTracker Pro

Cost: £257 / $320
From: First Light Optics

6 While iOptron's SkyGuider Pro is aimed at deep sky photography, the pared-down, and more compact iOptron SkyTracker Pro is aimed more at wide-angle nightscapes. Its payload capacity, at three kilograms, is much less than its stablemate and at 1.1 kilograms it is also lighter. As such it's more suitable for those wanting to carry a star tracker in their camera bag during trips and travel. It has a wider appeal than just nightscapes – in addition to tracking objects in the night sky, it can also follow the Sun and Moon and it has a half speed for capturing time-lapses. As a bonus, its internal battery can run for 24 hours. It sits at an affordable price point, and the supplied accessories include a counterweight and declination bracket to increase the payload.



VICTOR GLOVER

The NASA astronaut and SpaceX Crew Dragon pilot

Victor J. Glover is a NASA astronaut and Naval Aviator. In his first spaceflight mission, he served as the pilot on the Crew-1 flight of SpaceX's Crew Dragon capsule, which launched on 15 November 2020. Crew-1 was the first operational commercial crewed mission to the International Space Station (ISS) and the second such flight overall after SpaceX's Demo-2 test mission, which launched in May 2020. On Crew-1, Glover became the 15th black astronaut in space and the first black astronaut to stay for an extended period on the ISS, where he spent nearly six months as Flight Engineer in orbit as part of Expedition 64.

Glover was born in Pomona, California. In 1994, he graduated from Ontario High School in Ontario, California, continuing his education by pursuing an engineering degree at California Polytechnic State University in San Luis Obispo, from which he graduated in 1999. Earning his 'wings of gold' as a commissioned officer in the Navy in 2001, Glover piloted aircraft in the United States, Italy, Japan and the Middle East. Glover completed 3,000 flight hours in more than 40 different aircraft, as well as over 400 landings on aircraft carriers.

Between 2007 and 2010, he earned three master's degrees from three different institutions: a Master of Science in Flight Test Engineering from Air University at Edwards Air Force Base in California; a Master of Science in Systems Engineering at the Naval Postgraduate School in Monterey, California; and a Master of Military Operational Art and Science at Air University in Montgomery, Alabama. It was in 2012 when Glover was selected for the Legislative Fellowship, a year-long full-time assignment to the office of a member of the US House of Representatives or the Senate. During his time as a Legislative Fellow, Glover was chosen to become a NASA astronaut and later selected as one of eight members of the 21st NASA astronaut class. During the application process, Glover spoke about composing a limerick, which he used to joke about medical procedures that astronauts must undergo for spaceflight.

On 15 November 2020, Glover left Earth as pilot and second-in-command of Crew-1, SpaceX's first contracted, fully operational astronaut mission to the ISS. Upon his arrival at the space station on 17 November 2020, he became the first black astronaut to stay for an extended mission in orbit. Glover's preparations for Crew-1 in the summer of 2020 coincided with a global pandemic and widespread political protests about racial injustice. At the time, he spoke out on social media about the need to not just "stick to space". "Remember who is doing space. People are," he tweeted. "As we address extreme weather and pandemic disease, we will understand and overcome racism and bigotry so we can safely and together do space. Thanks for asking."

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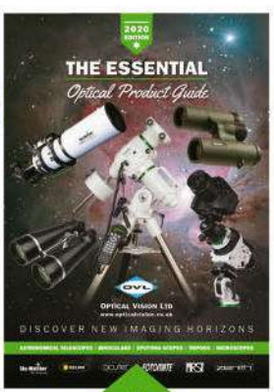

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